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THE STORY OF ATOMIC ENERGY.

IX.—PROGRESS UP TO THE FIRST ARTIFICIAL TRANSMUTATION.

By Dr. FREDERICK SODDY, F.R.S.*

SINGLE-ATOM METHODS.

IN the third decade of this century very great advances were made in the methods of detecting artificial production. So that from now on, the advances made arose, much more often than not, out of the study of individual atoms, and their behaviour, rather than by the former grosser methods, sensitive as these were beyond any previously employed in the physical sciences. This is possible, in the first place, because of the altogether unprecedented kinetic energy which these new radiant particles possess; but the great change of scale, from the most delicate previously known methods to those that now came into use, must not be overlooked in assessing the relation of the later work to what had gone before.

Quite early, as the simple spinthariscope of Sir W. Crookes had shown, it had been appreciated that a single α-particle is within the range of visual detection. For, in that little instrument, illustrated in Figs. 51 and 52, the phosphorescent glow of a zinc-sulphide screen being bombarded by the α-rays from an infinitesimal trace of bare radium, is resolved by a simple lens into a swarm of shooting stars, each of which is due to the impact on the screen of a single α-particle. The eyepiece lens C, in Fig. 52, is focused on the zinc-sulphide screen B, being bombarded by an infinitesimal trace of radium on the needle point A, the distance of which from the screen can be varied by the side-screw D. In the dark, with the eye rested, the glow of the screen is resolved by the lens C into a swarm of shooting stars. This was one of the first methods to be used, originally by Regener, for counting α-particles, and most of the work to be discussed in this period was done at first by such methods. Now they have been replaced by much less tiring and subjective ones, which belong to two different categories.

C. T. R. Wilson, who was one of the brilliant group of investigators in the Cavendish Laboratory, Cambridge, at the start, in 1899, of the theory of gaseous ionisation by this type of radiation, specialised on the importance, in meteorology, of these ions in the air acting as the centres upon which water drops condense from an atmosphere supersaturated with moisture to form rain, fog or mist. From this he developed a beautiful instrument, known as the Wilson expansion chamber, for rendering the actual tracks of these individual radiant particles visible as wisps of cloud. This, in due course, finally with the aid of stereoscopic photography and cinematography, developed into a most valuable method, even capable of giving accurate information on the dynamics of the collisions of radiant particles with the atomic nuclei in their path, from which their mass and energy could be inferred. Often in most elaborate batteries, in which the passage of a ray through one chamber is the cause of instantaneous photographic exposures in many others, it has, for example, been largely responsible for our present knowledge of the cosmical radiation. The principle of the Wilson apparatus is illustrated diagrammatically in Fig. 53. A cylinder with moving plunger P is closed by a glass plate W. The top of the plunger is covered with blotting paper moistened with Indian ink, and the sides of the cylinder are also black. Rays from the radioactive preparation enter from the side in the direction L, from a tube, traversing the air in the cylinder. By mechanical means, the plunger is suddenly lowered, expanding the moist air, causing it to be supersaturated and, if ionised, water drops to condense on the ions, so revealing the tracks of ionising radiations. Dust particles are first removed by a few preliminary expansions. During the sudden expansion, the electric field from the high-tension battery shown is broken, and is re-established on the up-stroke to clear the chamber of the ions produced in the previous expansion. The modern form of the apparatus, as made by the Cambridge Instrument Company, is shown in Figs. 54 and 55, and Figs. 56 and 57 are examples of the tracks of α-particles obtained with it. The tracks for α-rays, owing to the intense columnar ionisation they produce, appear as straight rays, occasionally showing abrupt deflection due to nuclear collisions. Those of the β-rays, on the other hand, appear as faint tortuous lines of the individual water droplets, as for these the ionisation produced is very much less and the β-particle is readily deflected by collision with the outer electronic systems of the atoms penetrated. In Fig. 57 one of the α-particle tracks near the centre shows two successive nuclear collisions and

FIG. 51.

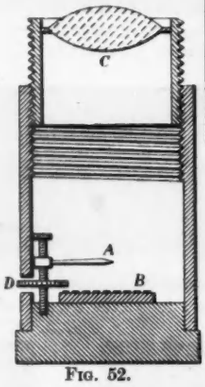


FIG. 52.

FIGS. 51 AND 52. THE SPINTHARISCOPE OF SIR WILLIAM CROOKES.

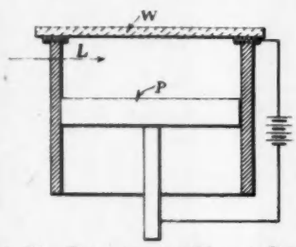


FIG. 53. PRINCIPLE OF WILSON CLOUD CHAMBER.

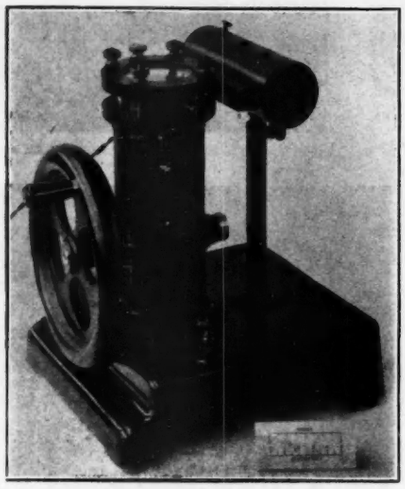


FIG. 54.

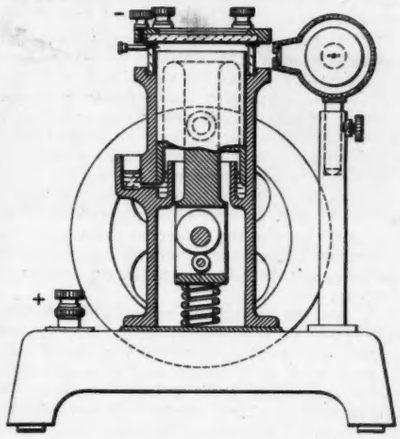


FIG. 55.

FIGS. 54 AND 55. WILSON CLOUD-CHAMBER APPARATUS; CAMBRIDGE INSTRUMENT COMPANY, LIMITED.

FIG. 56. ALPHA-RAYS FROM RADIUM IN CLOUD CHAMBER.

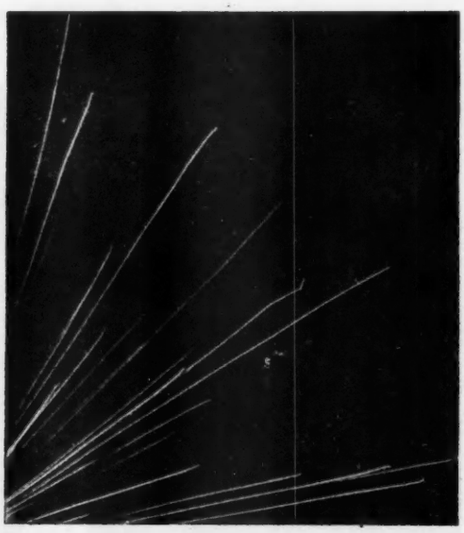


FIG. 57. ENLARGED VIEW OF ALPHA-RAY TRACKS.

and accurately studying the α- and β-rays and the similar radiant particles, soon, by the progress of high-tension electricity, to become capable of

* We have arranged with Dr. Soddy to publish his new book, *The Story of Atomic Energy*, in the form of a series of articles which are appearing at fortnightly intervals approximately. Dr. Soddy, however, retains the copyright, therefore no extract may be made from these articles without his permission.—ED. E.

the tortuous tracks due to the β-rays are also faintly shown in the original.

Amplification Methods.

The other method depends on the amplification of the ionisation, in the first place, by the collision of the ions with the neutral molecules of the gas, in an electric field of just insufficient strength to cause a spark to pass. This was originally studied by John, now Sir John, Townsend, also one of the original group referred to studying gaseous ionisation at the Cavendish Laboratory, Cambridge. The positive ion in gases is slightly heavier and less mobile than the negative ion, and the method depends on the latter only first acquiring the necessary velocity to ionise the molecules by collision. Under these conditions the ionisation, though greatly magnified, remains finite. When the positive ion also acquires the ionising velocity, the ionisation necessarily rises without limit so that an electric spark passes. First, in conjunction with the string-electrometer and photographic recording gear, these particles could be counted up to a rate of a thousand a minute. Fig. 58 illustrates the photographic registration of α-particles with the original Rutherford-Geiger counter and string electrometer; the upper record corresponds to the entrance of particles into the counter at a rate of 600 per minute, while the lower record corresponds to a rate of 900 per minute. In its present form, this principle is applied by what are termed Geiger counters, depending on the electric discharge from a sharp point, which is one of the simplest and most useful instrumental devices ever designed, and which responds equally to α- and β-particles. Fig. 59 shows the registration of α- and β-particles with the Geiger point counter. In this case, the upper record shows the registration of β-particles, and the lower record the registration of α-particles.

But now the thermionic valve, which in the third decade of this century made home radio-receiving sets possible, has been impounded into this same work, with results that a quarter of a century ago would have seemed incredible. A single particle can ring an electric bell, or otherwise announce itself. By means of an electronic counting device, known as the thyratron, they can operate mechanical counting gear, or be otherwise amplified in power sufficient to start other mechanical devices.

As an instance, a subject may hold an outstretched arm to a Geiger counter, and it will announce the time it takes for an ultra-homeopathic dose of a radioactive isotope to get there. If swallowed, it is said to take twenty minutes, but, if subcutaneously injected into the other arm, only as many seconds. This is now the scale of work on which we are entering. In radioactivity, if anywhere, never has the importance of the infinitesimal in science been better illustrated; never before, in the now historic phrase, did we owe so much to so little, if not, in the present temper of the world, possibly too much for all but too few.

The Nucleus and Astronomy.

Rutherford concluded, from exhaustive studies of the passage of α-particles through the various elements, that, for those above the atomic weight of copper (63), the collisions of α-particles with their nuclei were elastic, obeying the ordinary law of electrostatic repulsion. These experiments indicated a diameter of the nucleus of the order of only one ten-thousandth of that of the hydrogen atom. Since practically the whole mass is in the nucleus, this implies that its density must be something like a billion times greater than water, or fifty-thousand million times that of the densest substance known. Since then, the astronomers have found evidence that densities of this order do exist in some of the stars, notably the "white dwarfs." They even think that the normal course of stellar evolution, consequent on the loss of energy by radiation, is a periodic collapse of the star, with intense outburst of energy, into this degenerate form of "stripped" atoms, in which the outer shells of electrons are broken down and the matter assumes the form of closely packed nuclei and free electrons. Various intermediate stages of their degeneration, corresponding to successive loss by the atoms of the rings of electrons, from the outermost to the innermost K-ring, have been postulated, and it has been grandiloquently proclaimed that the heavens themselves bear witness to the Rutherford-Bohr atom.

THE STORY OF ATOMIC ENERGY.

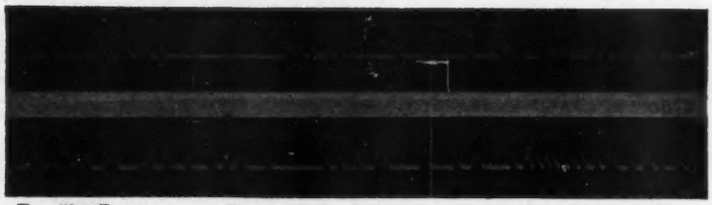


Fig. 58. Photographic Registration of Alpha-Particles with Rutherford-Geiger Counter and String Electrometer.

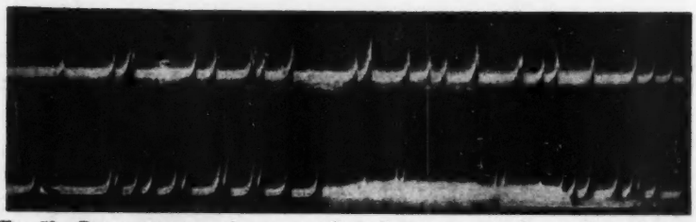


Fig. 59. Registration of Alpha- and Beta-Particles with Geiger Point Counter.

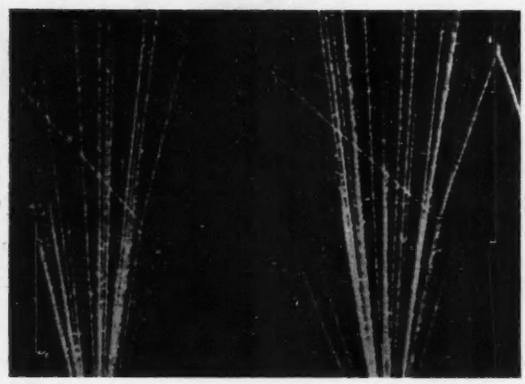


Fig. 60. Collision of Alpha-Particle with a Hydrogen Nucleus.

Fig. 61. Collision of Alpha-Particle with a Helium Nucleus.

Fig. 62. Collision of Alpha-Particle with an Oxygen Nucleus.

Fig. 63. Collision of Alpha-Particle with a Nitrogen Nucleus, Disintegrating It.

Radiant Protons.

But for our present story, the results with the lighter elements were of nearer terrestrial significance. For it was the nuclei of the light elements of odd atomic number that were first found to be disintegrated by the impact of α-particles. For hydrogen, especially, quite apart from this, the dynamics of the collision are unique, since the hydrogen nucleus is the only one lighter than the α-particle. Here, a head-on collision between the

THE STORY OF ATOMIC ENERGY.

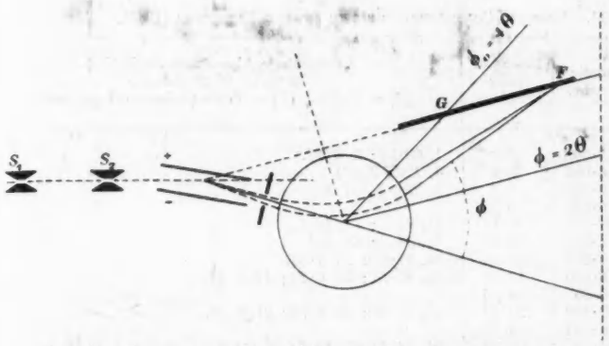


FIG. 64. PRINCIPLE OF ASTON'S FIRST MASS SPECTROGRAPH.

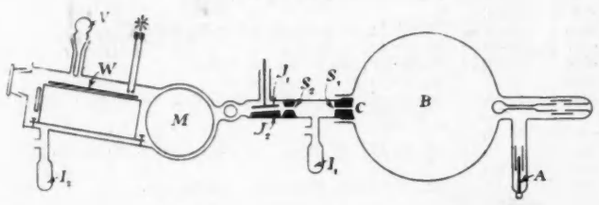


FIG. 65. FORM OF ASTON'S FIRST MASS SPECTROGRAPH.

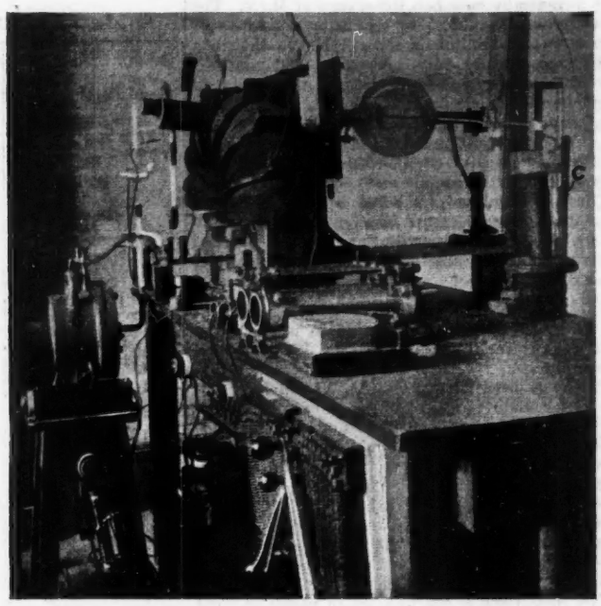


FIG. 66. ASTON'S ORIGINAL MASS SPECTROGRAPH IN THE CAVENDISH LABORATORY.

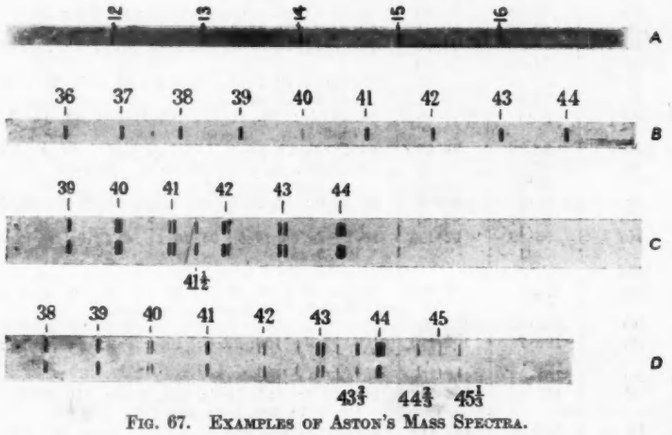


FIG. 67. EXAMPLES OF ASTON'S MASS SPECTRA.

two nuclei was expected to result in the hydrogen nucleus being propelled forwards, at a velocity considerably greater than, and with a range some four times, that of the α-particle propelling it. These radiant H-particles are free hydrogen nuclei—or protons as the singly positively charged hydrogen ion has been misnamed. They were first observed by Marsden in 1914, and later found to follow the prediction as regards their range. Their long range makes them very easy to observe. For, though the scintillations they produce in zinc-sulphide are feeble, they may be studied far beyond the distances penetrated by the α-rays, however powerful, just as the relatively feeble γ-rays can be studied alone by passing the radiation through a screen thick enough to absorb all the others. Figs. 60 and 61, opposite, due to Professor P. S. Blackett, show the elastic collision of an α-particle with a hydrogen atom (Fig. 60) and with a helium atom (Fig. 61). The former is an example of the more modern "stereographic" photographs showing the collision in two planes, from which the three-dimensional diagram of the collision can be constructed.

DISINTEGRATION OF LIGHT NUCLEI BY ALPHA-PARTICLES.

Then, in 1919-22, Rutherford found that a few such radiant protons resulted when the α-rays went through nitrogen gas, and that the range of these was greater by one-third than those given by hydrogen, though otherwise they were quite similar. The other light elements of odd atomic number, up to phosphorus, also produced them, though in ever smaller numbers. But those from aluminium had a range over three times as great as those from hydrogen, which corresponds to a kinetic energy greater than that of the α-particle producing it; also a large proportion are emitted in the backward direction. These facts clearly established that they resulted from the veritable break-up of the nuclei of the elements bombarded.

Only about one in a thousand million hydrogen atoms penetrated by the α-particles becomes a radiant proton, and only a few result per hundred thousand α-particles; per million α-particles, nitrogen gave about 20, and aluminium 8. The Wilson tracks in nitrogen were cinematographed by Harkins first, in the United States, and then by Blackett in England. The latter examined 23,000 photographs, containing 20 times as many α-ray tracks, to find only eight cases where the ejection of the light proton were revealed. Figs. 62 and 63, opposite, contrast the elastic collision of an α-particle with an oxygen atom—the short spur showing the latter recoiling after the collision (Fig. 62)—with the rare inelastic collision of the α-particle with a nitrogen atom (Fig. 63), the latter being disintegrated, ejecting a hydrogen nucleus giving a light straight track, and the recoiling complex giving the heavy track showing deflection by subsequent nuclear collisions. The important point was established that in no case was there any trace of the α-particle after such a collision. Long afterwards, when a great number of similar cases had been studied and this type of disintegration became known as one of the most common, it became certain that, in this first example to be observed, the helium nucleus had combined with the nitrogen nucleus, ejecting a proton, and forming the nucleus of an isotope of oxygen of mass 17, then unknown and not actually discovered till some years later.

Of the main fact of the proton being expelled from the nucleus struck, however, there never was any reasonable doubt. This, popularly dubbed splitting the atom, is usually considered to be the first case to be established of artificial transmutation, but is, more accurately, the first case of using the natural transmutation of one element to produce the transmutation of other elements. For full artificial transmutation, on the individual atom scale, however, the world had now not long to wait. The precise knowledge of the nature of these α- and β-particles led to the growing recognition that they were ions, moving with speeds that could be produced artificially by electric fields of sufficiently high, but easily calculable, potential. This, naturally, greatly stimulated the search for means to produce much higher voltages than the highest then possible. The large induction coils then used to generate X-rays did not usually attain a potential of even 100,000 volts, whereas the faster α-particles have energy that would require about four million volts to produce artificially.

THE ELECTRON-VOLT.

The useful new energy unit for single atoms and ions which has come into use, called the electron-volt (e.v.), is the product of the electronic charge e and the volt, and is equal to $1{\cdot}59 \times 10^{-12}$ erg. The thermal energy of a gas molecule at room temperature is about 0·04 e.v., and the chemical energy in the production of water from hydrogen and oxygen is some 3 e.v. In this unit, chemical energies never much exceed about 4 e.v. This is reflected in the voltage of primary and secondary battery cells never much exceeding two volts. But, in the new field, the unit is a million electron-volts (M.e.v.). For the electron and proton, which carry single atomic charges, the kinetic energy in M.e.v. is, numerically, the same as the voltage necessary

to impart the velocity corresponding to the kinetic energy as measured in this unit. But for the doubly-charged α-particles, the necessary voltage is numerically only half the energy in M.e.v. The energy of the fastest of the main α-particles of radium and thorium is some 8 M.e.v., though a few theoretically very interesting "long-range" α-particles are known—in the case of thorium in number about one in 5,000 of, and, in range half again as great as, the fastest normal α-rays.

In these units, 1 M.e.v. is almost equal to the loss of atomic mass of one-thousandth of a unit, or, exactly, 1 unit of atomic mass equals 931·6 M.e.v. Thus the expulsion of the fast α-particle occasions an absolute loss of atomic mass, over and above the four units carried away by the departing particle, of some 0·008 because of the energy with which it is expelled.

Aston's Work on Isotopes.

It is necessary now to revert to isotopes and first briefly recall how in 1913 Sir. J. J. Thomson had obtained by the positive-ray method inconclusive evidence that neon (At. Wt. 20·183) contained, in addition to a main isotope of mass number 20, a few per cent. of one of mass number 22, which would account for the atomic weight not being integral. The evidence was inconclusive because of the possibility that this mass number might arise from the doubly-charged carbon-dioxide molecule, CO_2^{++}, or similar impurity of the many, always liable to show in high-vacua discharges. In these original experiments what is called the "parabola-method" was used, in which the electric and magnetic deflections of the ions are in planes at right angles to one another and to the direction of motion of the ions, causing those of the same m/e value to give a parabolic trace on the photographic plate, due to their travelling with a wide range of velocity and kinetic energy. Aston, after the First World War, modified this disposition by causing the two deflections to be in the same plane in opposite directions—an arrangement now universal in all this work—and so brought in an invaluable focusing effect, improving the sensitiveness and accuracy of the method almost beyond recognition. With this new weapon he quickly established that many of the commonest elements were mixtures of isotopes, one of the first successes being with chlorine (At. Wt. 35·457) which consists of two isotopes of mass numbers 35 and 37, in proportion to give this atomic weight. Two broad generalisations, the theoretical importance of which it would be impossible to overestimate, ultimately transpired, the first that the mass-numbers of the individual isotopes are all approximately integral, in terms of oxygen as 16, and the second that the small departures of the exact values from integers, as one proceeds from one end of the Periodic Table to the other, are a continuous function of the atomic masses, as will be gone into in due course.

In 1919, Aston built his first mass spectrograph in the Cavendish Laboratory, in which these great improvements in the Thomson technique, for determining the mass of positive ions, were incorporated. This first instrument proved to be capable of measuring their mass to one part in 1,000 as the maximum error. This again was soon followed by much more accurate instruments, designed by him and by the Continental and American workers, so that they now constitute, particularly those built in America, one of the most marvellous and accurate measuring instruments invented by the mind of man. Fig. 64, on page 219, illustrates the principle of Aston's first mass spectrograph. The beam of positive rays canalised by slots S_1 and S_2 pass through the electrostatic field between charged plates, which deflects them downwards, and then through the magnetic field, which deflects them upwards in the same plane in such a way that the divergent beam is brought to a focus on the line GF as a mass-spectrum, G being the low and F the high mass end. In Fig. 65, page 219, C is the perforated concave cathode and A the anode of the discharge tube B. The positive rays pass through slits S_1 S_2, through the electric field J_1 J_2 and the magnetic field M, to the photographic plate W. I_1 I_2 are charcoal bulbs cooled in liquid air to maintain the vacuum, and an arrangement V allows the plate to be wound up for successive exposures.

THE STORY OF ATOMIC ENERGY.

TABLE II. Isotopic Composition of the Stable Elements (1945).

Atomic Number.	Element.	Atomic Weight.	Range of Mass Numbers.	Percentage Abundance (in *italics*) in Order of Abundance (S) = Single; (T) = Trace (below 0·01 per cent.).
1	H	1·008	1–2	1, *99·98*; 2, *0·02*.
2	He	4·003	3–4	4, *100*; 3, (T).
3	Li	6·940	6–7	7, *92·5*; 6, *7·5*.
4	Be	9·02	9 (S)	
5	B	10·82	10–11	11, *81·6*; 10, *18·4*.
6	C	12·010	12–13	12, *98·9*; 13, *1·1*.
7	N	14·008	14–15	14, *99·62*; 15, *0·38*.
8	O	16·000	16–18	16, *99·76*; 18, *0·20*; 17, *0·04*.
9	F	19·00	19 (S)	
10	Ne	20·183	20–22	20, *90·00*; 22, *9·73*; 21, *0·27*.
11	Na	22·997	23 (S)	
12	Mg	24·32	24–26	24, *77·4*; 25, *11·5*; 26, *11·1*.
13	Al	26·97	27 (S)	
14	Si	28·06	28–30	28, *89·6*; 29, *6·2*; 30, *4·2*.
15	P	30·98	31 (S)	
16	S	32·066	32–36	32, *95·1*; 34, *4·2*; 33, *0·74*; 36, *0·016*.
17	Cl	35·457	35–37	35, *75·4*; 37, *24·6*.
18	A	39·944	36–40	40, *99·63*; 36, *0·31*; 38, *0·06*.
19	K	39·096	39–41	39, *93·4*; 41, *6·6*; 40, *0·01*.
20	Ca	40·08	40–48	40, *96·97*; 44, *2·06*; 42, *0·64*; 48, *0·185*; 43, *0·145*; 46, (T).
21	Sc	45·10	45 (S)	
22	Ti	47·90	46–50	48, *73·45*; 46, *7·94*; 47, *7·75*; 49, *5·52*; 50, *5·34*.
23	V	50·95	51 (S)	
24	Cr	52·01	50–54	52, *81·6*; 53, *10·4*; 50, *4·9*; 54, *3·1*.
25	Mn	54·93	55 (S)	
26	Fe	55·85	54–58	56, *91·6*; 54, *6·0*; 57, *2·1*; 58, *0·28*.
27	Co	58·94	57–59	59, *99·8*; 57, *0·2*.
28	Ni	58·69	58–64	58, *67·4*; 60, *26·7*; 62, *3·8*; 61, *1·2*; 64, *0·88*.
29	Cu	63·54	63–65	63, *70·13*; 65, *29·87*.
30	Zn	65·38	64–70	64, *50·9*; 66, *27·3*; 68, *17·4*; 67, *3·9*; 70, *0·5*.
31	Ga	69·72	69–71	69, *61·2*; 71, *38·8*.
32	Ge	72·60	70–76	74, *37·1*; 72, *27·3*; 70, *21·2*; 73, *7·9*; 76, *6·5*.
33	As	74·91	75 (S)	
34	Se	78·96	74–82	80, *48·0*; 78, *24·0*; 76, *9·5*; 82, *9·3*; 77, *8·3*; 74, *0·9*.
35	Br	79·916	79–81	79, *50·6*; 81, *49·4*.
36	Kr	83·7	78–86	84, *57·11*; 86. *17·47*; 82, *11·53*; 83, *11·53*; 80, *2·01*; 78, *0·38*.
37	Rb	85·48	85–87	85, *72·8*; 78, *27·2*.
38	Sr	87·63	84–88	88, *82·56*; 86, *9·86*; 87, *7·02*; 84, *0·56*.
39	Y	88·92	89 (S)	
40	Zr	91·22	90–96	90, *48·0*; 92, *22·0*; 94, *17·0*; 91, *11·5*; 96, *1·5*.
41	Nb	92·91	93 (S)	
42	Mo	95·95	92–100	98, *24·1*; 96, *16·6*; 95, *16·1*; 92 *14·9*; 97, *9·65*; 94, *9·40*; 100, *9·25*.
43	[Ma]			
44	Ru	101·7	96–104	102, *31·34*; 104, *18·27*; 101, *16·98*; 99, *12·81*; 100, *12·70*; 96, *5·68*; 98, *2·22*.
45	Rh	102·91	103 (S)	
46	Pd	106·7	102–110	106, *27·2*; 108, *26·8*; 105, *22·6*; 110, *13·5*; 104, *9·3*; 102, *0·8*.
47	Ag	107·88	107–109	107, *51·9*; 109, *48·1*.
48	Cd	112·41	106–116	114, *28·0*; 112, *24·2*; 111, *13·0*; 110, *12·8*; 113, *12·3*; 116, *7·3*; 106, *1·4*; 108, *1·0*.
49	In	114·76	113–115	115, *95·5*; 113, *4·5*.
50	Sn	118·70	112–124	120, *28·5*; 118, *22·5*; 116, *15·5*; 119, *9·8*; 117, *9·1*; 124, *6·8*; 122, *5·5*; 112, *1·1*; 114, *0·8*; 115, *0·4*.

Fig. 66, page 219, is reproduced* from a photograph of the original mass spectrograph, set up in 1919, by F. W. Aston in the Cavendish Laboratory, and now in the Science Museum, South Kensington. The induction coil is housed under the table; the gas being examined is stored over mercury in C, and G is the rotary mercury vacuum pump. Aston's second mass spectrograph was built in 1925, and had an accuracy of about 1 in 10,000, sufficient to separate the mass-lines of every known element. But some unexpected difficulties arose, interfering seriously with the resolving power of the instrument, through a polarisation effect of the electric field, which he and later workers have sought to avoid by using wider gaps and higher potentials, and also by re-arrangement of the whole system. Aston's third mass spectrograph was completed in 1937, and a few examples of the work of these instruments are given. The accuracy had been enormously increased and, in favourable cases, was as great as 1 in 100,000, the error in general being only three or four times this. By that time the practice had gradually developed of "natural bracketing," which meant bringing on the same photograph two different ions of the same mass number, such as the singly-charged oxygen atom, O^+, and the singly-charged methane molecule, CH_4^+, both of mass number 16, so that the doublet revealed the difference in the exact atomic weights of hydrogen and carbon from the oxygen = 16 standard. In this connection it must be borne in mind that what is really measured is not m but m/e, so that a singly-charged ion of mass m shows the same mass-number as a doubly-charged ion of mass $2m$, or triply-charged ion of mass $3m$, and so on. The determination of the number of charges on the ion is always inferential, if not guesswork, but no serious error seems to have arisen through this. Aston had also cleverly developed the hydrocarbon ions, that appear in such spectra, to give a series of lines differing by unity. Thus the first "carbon group" consists of the singly-charged positive ions, C^+, CH^+, CH_2^+, CH_3^+, CH_4^+, giving the numbers 12, 13, 14, 15 and 16; the second carbon group similarly with two atoms of carbon to the ion, gives the numbers 24 to 30, and the "third carbon group," with three atoms of carbon in each ion, gives the numbers from 36 to 44, C_3^+ to

* Figs. 64, 65 and 66 have been copied from Dr. Aston's book *Mass Spectra and Isotopes*: Edward Arnold and Company, London, 1933.

THE STORY OF ATOMIC ENERGY.

TABLE II—*continued.*

Atomic Number.	Element.	Atomic Weight.	Range of Mass Numbers.	Percentage Abundance (in *italics*) in Order of Abundance (S) = Single; (T) = Trace (below 0·01 per cent.).
51	Sb	121·76	121–123	121, *56·0*; 123, *44·0*.
52	Te	127·61	120–130	130, *33·1*; 128, *32·8*; 126, *19·0*; 125, *6·0*; 124, *4·5*; 122, *2·9*; 123, *1·6*; 120, (T).
53	I	126·92	127 (S)	
54	X	131·3	124–136	132, *26·96*; 129, *26·23*; 131, *21·17*; 135, *10·54*; 136, *8·95*; 130, *4·07*; 128, *1·90*; 124, *0·094*; 126, *0·088*.
55	Cs	132·91	133 (S)	
56	Ba	137·36	130–138	138, *71·7*; 137, *11·3*; 136, *7·8*; 135, *6·6*; 134, *2·42*; 130, *0·101*; 132, *0·097*.
57	La	138·92	139 (S)	
58	Ce	140·13	136–142	140, *89·0*; 142, *11·0*; 138, (T); 136, (T).
59	Pr	140·92	141 (S)	
60	Nd	144·27	142–150	142, *25·95*; 144, *22·6*; 146, *16·5*; 143, *13·0*; 145, *9·2*; 148, *6·8*; 150, *5·95*.
61				
62	Sm	150·43	144–154	152, *26·0*; 154, *20·0*; 147, *17·0*; 149, *15·0*; 148, *14·0*; 150, *5·0*; 144, *3·0*.
63	Eu	152·0	151–153	153, *50·9*; 151, *49·1*.
64	Gd	156·9	152–160	158, *23·45*; 160, *20·87*; 156, *20·59*; 157, *16·42*; 155, *15·61*; 154, *2·86*; 152, *0·20*.
65	Tb	159·2	159 (S)	
66	Dy	162·46	158–164	164, *28·0*; 163, *24·0*; 162, *24·0*; 161, *22·0*; 160, *1·5* 158, *0·1*.
67	Ho	164·94	165 (S)	
68	Er	167·2	162–170	166, *32·9*; 168, *26·9*; 167, *24·4*; 170, *14·2*; 164, *1·5*; 162, *0·1*.
69	Tm	169·4	169 (S)	
70	Yb	173·04	168–176	174, *29·58*; 172, *21·49*; 173, *17·02*; 171, *14·26*; 176, *13·38*; 170, *4·21*; 168, *0·06*.
71	Lu	174·99	175–176	175, *97·5*; 176, *2·5*.
72	Hf	178·6	174–180	180, *35·14*; 178, *27·13*; 177, *18·47*; 179, *13·85*; 176, *5·3*; 174, *0·18*.
73	Ta	180·88	181 (S)	
74	W	183·92	180–186	184, *30·1*; 186, *29·8*; 182, *22·6*; 183, *17·3*; 180, *0·2*.
75	Re	186·31	185–187	187, *61·8*; 185, *38·2*.
76	Os	190·2	184–192	192, *41·0*; 190, *26·4*; 189, *16·1*; 188, *13·3*; 187, *1·64*; 186, *1·58*; 184, *0·018*.
77	Ir	193·1	191–193	193, *61·5*; 191, *38·5*.
78	Pt	195·23	192–198	195, *35·3*; 194, *30·2*; 196, *26·6*; 198, *7·2*; 192, *0·8*.
79	Au	197·2	197 (S)	
80	Hg	200·61	196–204	202, *29·56*; 200, *23·26*; 199, *17·03*; 201, *13·17*; 198, *10·11*; 204, *6·72*; 196, *0·15*.
81	Tl	204·39	203–205	205, *70·9*; 203, *29·1*.
82	Pb	207·21	204–208	208, *52·3*; 206, *23·6*; 207, *22·6*; 204, *1·5*.
83	Bi	209·00	209 (S)	
84	Po	210		
85				
86	Rn	222		
87				
88	Ra	226·05		
89	Ac	227		
90	Th	232·12	232 (S)	
91	Pa	231		
92	U	238·07	234–238	238, *99·28*; 235, *0·71*; 234, (T).

$(C_2 H_3)^+$. These served as useful fiducial lines against which any other ion of the same mass number could be bracketed. Examples of Aston's mass-spectra are shown in Fig. 67, page 219, taken, except the first *A*, with his third mass-spectrograph. *A* was taken with the second mass spectrograph and shows the "first carbon group," the mass number 16 being a bracket of oxygen, O^+, with methane, CH_4^+, for the first time clearly separated, though differing by only 0·036 in mass. *B* shows the "third carbon group" with mass numbers 36 to 44 due to the ions C_3^+ to $(C_2 H_3)^+$. *C* shows this group bracketed against the doubly-charged ions of the isotopes of krypton, of mass numbers 82, 83, 84 and 86, the doubling at 40 and 44 being due, respectively, to argon and carbon-dioxide impurities. *D* shows the same group bracketed with the triply-charged ions of the xenon isotopes; 129, giving the doublet at 43; 131, giving the line at $43\frac{2}{3}$; 134, giving the line at $44\frac{2}{3}$; and 136, giving the line at $45\frac{1}{3}$.

By 1931, out of 64 elements examined, only 22 were found to be single. The rest were mixtures of isotopes, the most complex being tin (Atomic Weight 118·7, Atomic No. 50), with 11 isotopes ranging in mass from 112 to 124. By 1945, with more refined methods, for 83 elements there were some 283 isotopes, but only some 20 elements are single, though in many the proportion of the accompanying isotopes is minute. Table II, on this and the opposite pages, is a table of the elements giving their serial numbers in the sequence, now called the Atomic Number, Atomic Weights, and particulars of their isotopic composition. It is not too much to say, as already said in different words, that the complexity of the subject of atomic energy is now confined to the extraordinarily large number of different atoms in existence. Table II shows only the stable types, capable of permanent existence as distinct chemical elements. Besides these there are a comparable number of unstable atoms outside the range of mass-number given in Table II, which is still continuing to increase rapidly as their investigation continues.

(To be continued.)

INSTITUTE OF PETROLEUM.—In order to provide for those connected with the petroleum industry, especially younger persons and the less technical, who are not sufficiently catered for by the London meetings of the Institute of Petroleum, a London Branch has been formed. The inaugural meeting of the new branch took place on Thursday, March 4, at the headquarters of the Institute, Manson House, 26, Portland-place, London, W.1. Further information may be obtained from the honorary secretary, Mr. N. E. F. Hitchcock, Stifford Cottage, High-street, Cranford, Middlesex.

LITERATURE.

An Introduction to Aerodynamic Compressibility. By J. BLACK, M.Sc. Bunhill Publications, Limited, 12, Bloomsbury-square, London, W.C.1. [Price 18*s.* net.]

THE theory and practice of aerodynamics have developed very rapidly in recent years, particularly in the branch dealing with high-speed flow. It is not surprising, therefore, that text-books are urgently needed, both by the design staffs of aircraft firms and by students of aerodynamics; nor that few writers are to be found willing to prepare them, a task which requires courage as well as a profound knowledge of the subject, when it is obvious that many of the theories and hypotheses accepted at the time of writing may have been discarded by the time the book is published. Mr. Black undoubtedly had courage in writing this book, though there is not a great deal in it that goes beyond the knowledge available seven years ago.

The scope of the book is best indicated by the chapter headings, covering "General Considerations of Compressible Flow," "Energy Relations and Thermodynamics of Flow," "Flow through Nozzles, and High-speed Wind Tunnels," "Formation and Propagation of Shock Waves," "Theoretical Analysis of Flow past Various Bodies," and "High-speed Flight," with "Design Aspects of Compressibility." An appendix deals with optical systems for the photography of high-speed flow of gases, and another provides a table of two-seventh powers. In the space of less than a hundred pages, the author aims to cover the whole field of compressible flow, from the point of view of the designer and of the aerodynamic student, but, in fact, the book has little to offer to the former. Half of Chapter 6, which is the only chapter devoted to the application of compressible-flow theory to aircraft, deals with the simple Ackeret theory for two-dimensional supersonic flow; the remainder is inadequate and out of date. In the other chapters, there is undoubtedly much of value for the student, to whom the subject is new; but he would need to have a competent teacher at hand to clarify some theoretical aspects of the subject.

No clear distinction is drawn between changes occurring with no heat flow to or from the external medium (adiabatic changes) and changes for which there is no increase of entropy (isentropic or reversible changes). It appears from the footnotes on pages 24 and 56 that the author was aware of the distinction, but a fundamental point of this kind should have been given great emphasis in the text. The subject of dynamic similarity is dismissed in some ten lines, no mention being made there of the parts played by the Reynolds number, the Prandtl number, and the ratio of the specific heats. On pages 41 and 42, it is suggested that the effect of the Reynolds number on compressibility phenomena can be safely ignored, but it is known now that, in the transonic range, this effect is of the greatest importance. On page 45 there is a statement that, in supersonic flow, the forward stagnation point moves to the bow wave ahead; a brief study of the subsequent remarks on shock waves will show that this is incorrect. The discussion on pages 68 and 69 of the linearised theory for subsonic flow is somewhat obscure, and is unnecessarily restricted to two-dimensional flow. The statement on page 69 that the drag coefficient of an aerofoil section varies with Mach number as the Glauert factor is incorrect. In the treatment of the method of characteristics (pages 77-81), there is little attempt to explain their physical significance or the meaning of the numbers attached to them. The remarks on pages 90 and 91 discussing the interaction of shock waves and boundary layers need modifying and expanding in the light of more modern ideas on the effect of Reynolds number and the state of flow in the boundary layer. It should not be inferred from the foregoing, however, that Mr. Black's book is without value. For those whose work is not directly concerned with the more advanced aspects of the subject, the book provides a pleasantly written synopsis that will quickly convey the essential ideas. The figures are clear and the book is well printed; the Schlieren pictures of shock-wave patterns are particularly well reproduced.

BRITTLE FAILURE OF SHIP PLATES.

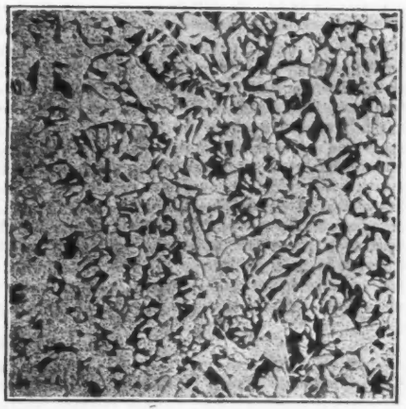


FIG. 35. PLATE 7B. × 50.

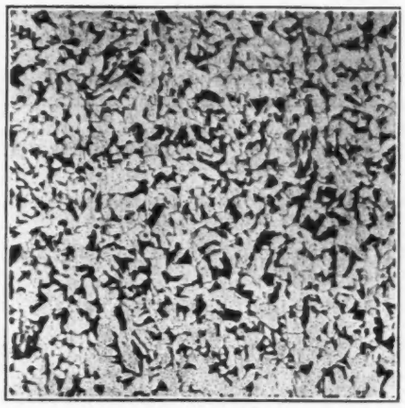


FIG. 36. PLATE 4B. × 50.

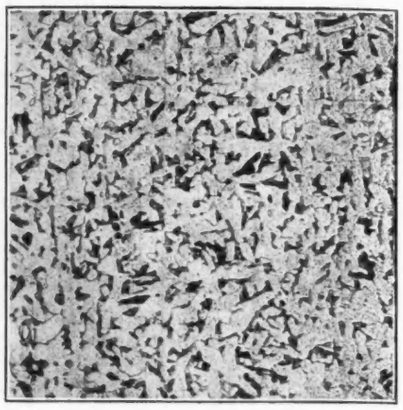


FIG. 37. PLATE 2A. × 50.

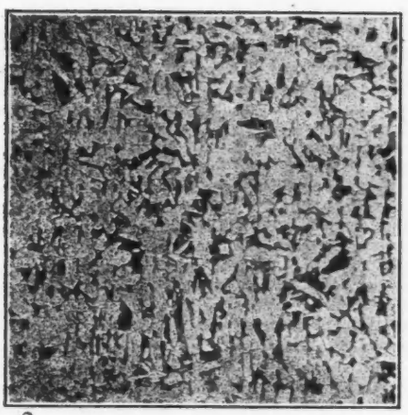


FIG. 38. PLATE 9A. × 50.

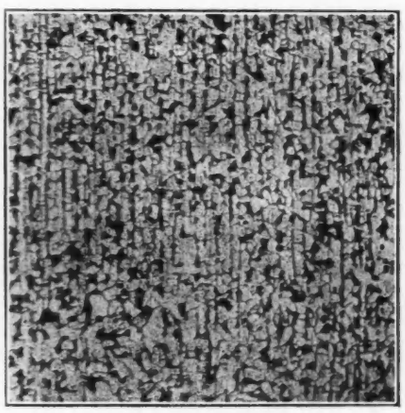


FIG. 39. PLATE 4A. × 50.

FIG. 40. PLATE 10A. × 50.

BRITTLE FRACTURE IN MILD-STEEL PLATES—II.

(*Continued from page* 210.)

The structure of the British plates was quite uniform throughout the series, and there is little to choose between them, except a slight increase in coarseness in the 1 in. thick plates (Fig. 35) compared with the ¾ in. thick plates (Fig. 36). In most of the American plates, the structure was very similar to that of the British plates of corresponding thickness, representative micrographs being shown in Fig. 37 (¾ in.) and Fig. 38 (1 in.). There were, however, three exceptions. Plate No. 4A (Fig. 39), had a much finer structure, indicating a lower finishing temperature; this plate had the highest Izod of the series, the additional refinement of the grain having compensated for the low manganese content. In the 1 in. thick series, Plates 10A and 11A have abnormally coarse structures (Fig. 40,) which, combined with a very low manganese, explain the low Izod values obtained.

It was next decided to ascertain the response of the two categories of steel to the influence of normalising and annealing, the latter treatment being introduced to give some indication of what would be likely to happen if the plates were stacked at the mill. For the purpose of these tests, six American and four British plates were selected to cover all the variables of composition, with particular reference to manganese. The dimensions of the test-pieces subjected to heat treatment were kept approximately constant throughout (6 in. by 1 in.). Test results are summarised in Table VI for the American plates and in Table VII for the British plates. The normalised plates were air-cooled from 900 deg. C., and the annealed plates were furnace-cooled from the

TABLE VI.—AMERICAN PLATES, NORMALISED AND ANNEALED.

Plate No.	Mn, per cent.	Normalised. Izod, ft.-lb. (i)	(ii)	(iii)	Mean.	Annealed. Izod, ft.-lb. (i)	(ii)	(iii)	Mean.	Decrease, per cent.
11A— ..	0·28	34	29	34	29	19	14	14	14	52
X ..		28	25	25		12	10	13		
3A— ..	0·31	49	51	50	40	17	15	15	13	62
X ..		31	31	30		10	11	10		
2A— ..	0·34	57	61	57	52	21	24	23	20	62
X ..		47	44	45		17	17	17		
6A— ..	0·41	65	67	66	52	31	29	30	27	48
X ..		35	46	33		23	25	25		
9A— ..	0·41	57	58	64	55	24	26	27	24	56
X ..		52	46	55		24	20	23		
3A— ..	0·47	54	54	57	47	34	33	33	27	43
X ..		39	38	37		21	21	21		

TABLE VII.—BRITISH PLATES, NORMALISED AND ANNEALED.

Plate No.	Mn, per cent.	Normalised. Izod, ft.-lb. (i)	(ii)	Mean.	Annealed. Izod, ft.-lb. (i)	(ii)	Mean.	Decrease, per cent.
6B—	0·56	63	65	56	45	45	38	32
X		48	50		31	30		
1B—	0·57	60	59	50	42	45	37	26
X		41	42		32	30		
7B—	0·59	63	63	52	49	44	40	23
X		40	41		35	31		
4B—	0·62	59	60	50	46	44	38	24
X		42	39		30	31		

same temperature, the cooling rate being 150 deg. C. per hour.

In the normalised condition, consistently good Izods of about 50 ft.-lb. are obtained in all plates with manganese over 0·30 per cent., but the significant factor from the practical viewpoint is the Izod value obtained after slow cooling and its relation to the manganese content. The lower the manganese, the greater is the reduction in the Izod value on slow cooling; hence the desirability of keeping this element above approximately 0·50 per cent. to ensure adequate notch toughness.

A series of tests was carried out on four American plates, Nos. 2A, 5A, 6A and 10A, with manganese contents from 0·30 per cent. to 0·47 per cent., also on three British plates with manganese contents of 0·57 per cent. to 0·62 per cent. For convenience, the Charpy testing machine was used with the standard Izod notch. In each case, length test pieces in the normalised condition were tested at 0 deg. C. and at 20 deg. C.; the results obtained are shown in Table VIII, herewith. The crystalline percentage of the fractures is shown in brackets. The results clearly demonstrate the beneficial effect of manganese in preserving notch toughness at temperatures down to freezing point.

For three of the above steels, additional impact tests were carried out over a wider range of temperature to determine the shape of the temperature impact curves shown in Fig. 41, herewith. These illustrate the influence of manganese, not only in increasing the impact value at ordinary temperatures but also in decreasing the temperature at which the transition from tough to brittle fracture occurs.

The significance of strain ageing in relation to brittle fracture in mild steel is apparent. Unfortunately, the time available did not permit an

TABLE VIII.—*Notch Tests; Effect of Manganese.*

Plate No.	Mn, per cent.	Impact Test, ft.-lb.	
		20 deg. C.	0 deg. C.
10A	0·30	25 (75)	6 (100)
2A	0·34	58 (50)	17 (90)
6A	0·41	66 (10)	22 (80)
5A	0·47	55 (50)	33 (80)
1B	0·57	60 (30)	33 (80)
7B	0·59	63 (10)	36 (80)
4B	0·62	60 (30)	39 (70)

investigation of the relative susceptibility of the steels in question to this phenomenon. The problems involved in such an investigation will be appreciated from the temperature-impact curves shown in Fig. 42, herewith, which illustrate the well-known effect of grain size and of strain ageing on the same cast of a low-carbon basic open-hearth mild steel (10 per cent. crystalline).

Attention is directed to the characteristic "S" shape of the curves, denoting a transition from tough to brittle fracture over a critical temperature range which may be extremely narrow. The position of this critical range on the temperature scale is taken as a measure of the susceptibility to strain-ageing of the steel—the lower the range the less the susceptibility, and vice versa.

It should be emphasised that these curves for the strain-aged specimens are based on the usual accelerated test, involving 10 per cent. strain with subsequent heating for ½ hour at 250 deg. C. Under these conditions, all the steels discussed in this report gave very low impact values at room temperature. It is possible, however, that, under less drastic testing conditions, the susceptibility of the steels would vary.

The foregoing investigations have been concerned mainly with certain metallurgical factors which affect the notch toughness of mild-steel ship plates, since it seems obvious that anything which can be done to retain adequate notch toughness, under all conditions of service, will minimise the risk of the type of failures which have occurred in these American ships. It is assumed, of course, that the Izod impact test is a suitable criterion of susceptibility or otherwise of steel to brittle fracture under service conditions; an assumption which appears justified from the fact that, in practice, such failures take place only in the presence of a notch.

The beneficial effects of manganese have been clearly demonstrated, and it is recommended that the practice, which is common in the United States, of working to a minimum manganese content of 0·50 per cent. should be adhered to, at any rate for thicker plates of sizes over ½ in.

The additional benefits to be derived from efficient normalising are well known, but it is not considered that the additional cost would be justified. The possibilities in this direction, however, may be worth considering for the thicker plates, on the basis of a reduction in scantlings to offset the additional cost of the steel.

The use of the so-called non-ageing steels immediately suggests itself but, unfortunately, in the light of present knowledge, the production of such steels

Fig. 41.

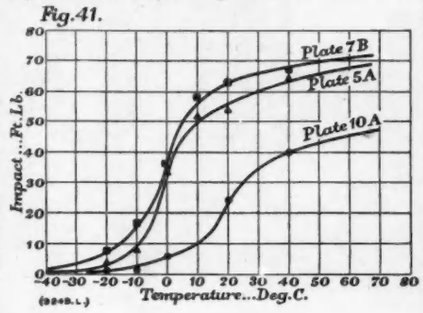
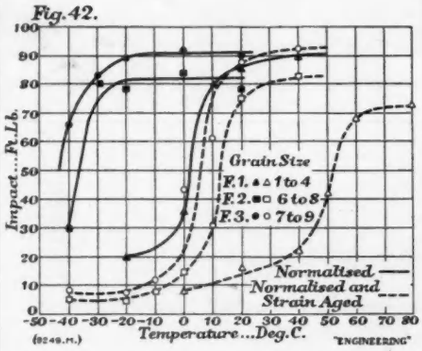


Fig. 42.



for ship plates is not an economical proposition. It is obvious that, the tougher the steel is in its initial condition, the less serious will be the effects of small amounts of strain, followed by ageing. It should be the aim of the steelmakers, therefore, to provide as tough a steel as is practicable. At the same time, it is suggested that the shipyards might consider the practicability of minimising conditions which give rise to strain ageing. The cause of strain ageing is by no means clear, and research work is proceeding with the object of elucidating a problem which is of considerable practical importance in relation to the failure of these ships. In conclusion, it should be pointed out that, while the foregoing investigations have dealt solely with the metallurgical aspect, the question of design is of equal importance, since failures of the type experienced are confined to welded ships.

(To be continued.)

THE INSTITUTE OF INDUSTRIAL ADMINISTRATION.—Lord Forrester, M.A., was elected chairman, in succession to Mr. Harold Whitehead, at the annual general meeting of the Institute of Industrial Administration, held in London on February 28. At the same meeting, it was announced that the following had been elected to the Council of the Institute: Edward Meigh, M.B.E., H. W. Broadbent, J. Riddoch, L. G. S. Mason, R. W. Osborn, and A. B. Lowndes. Mr. A. Roberts was appointed honorary treasurer, in succession to Mr. James E. Currie. The total membership of the Institute, as stated in the address of the retiring chairman, was 4,390 at the end of December, 1947; but Mr. Whitehead added that the total to the date of the annual meeting was 4,880, which meant that the membership had practically doubled during his two years in office. The vice-chairman, Mr. H. E. G. West, presented the report of the committee appointed to negotiate the basis of co-operation with the Government-sponsored British Institute of Management. Lord Forrester presided at the luncheon which followed the meeting.

TROPICAL ROOF CONSTRUCTION.

SOME of the firms which have been engaged on the production of "Arcon" temporary pre-fabricated houses have now introduced a light-weight easily transported and easily erected roof to meet the requirements of engineers concerned with colonial development. The roof is known by the same name, "Arcon," and is distributed by Messrs. Taylor Woodrow Construction Limited, 25, Wilton-road, London, S.W.1. While reasonably satisfactory materials for walls and floors are usually available overseas, it is contended that there is often some difficulty in roofing a building. The Arcon roof will, it is hoped, meet this demand.

The supporting posts, or columns, and the frame of the roof, in bays of 30-ft. span and 10 ft. long, are made of steel tubes. The columns provide a height to the eaves of 7 ft. 6 in. Each is inserted in a concrete foundation to a depth of about 1 ft., and has an arrangement of flanges at the top for attaching to the truss and purlins. The rafters of the trusses are arched to form a ridge roof, and the lower tie-beam is also arched. Each truss consists of two symmetrical triangular frames, known as half-trusses and fabricated with lattice bracing from steel tubes. Two half-trusses are joined directly at the lower centre corners, and by a bracing tube at the upper centre corners, to form a complete truss. The outer corner of each half-truss is bolted to the top of a column. In each bay there are eight purlins attached to the rafters, seven purlins attached to the tie-beams, and a purlin at each eave. Corrugated asbestos-cement sheets are fastened to the upper purlins, over the whole area of the roof, to form an outer roof, and to the under side of the lower purlins to form an inner roof; the latter sheets do not extend as far as the eaves, but a space is formed between the upper and lower sheets which permits air to circulate in the roof.

The material required for erecting a three-bay structure, 30 ft. by 30 ft., weighs approximately 5 tons, and consists of eight columns, 105 lb. each; 51 purlins, 47 lb. each; four truss braces; eight half-trusses, 187 lb. each; 54 straight sheets and 18 curved sheets; and three bags of bolts. The framing, without sheets, can be erected by unskilled labour in approximately 50 man-hours. All steel members are protected by hot-dip galvanising. The Arcon tropical roof is thus highly resistant to atmospheric corrosion; it is also designed to prevent insects from attacking the material of the structure or infesting the roof. It can be used for a variety of purposes, such as offices, warehouses, schools, bungalows, hostels, etc., and by erecting walls up to the edges of the inner roof, a verandah is provided, and the circulation of air in the roof ensures cool conditions inside the building. The principal components of Arcon roofs are manufactured by Messrs. Stewarts and Lloyds, Limited, and Messrs. Turners Asbestos Cement Company, Limited.

ITALIAN METALLURGICAL ASSOCIATION.—It has been announced that the second national meeting of the Associazione Italiana di Metallurgia will be held in Milan from April 23 to 25. The meeting was to have been held earlier, but had to be postponed. One of the three days will be devoted to discussions on papers dealing with corrosion and the ageing of metals, and the other two days will be utilised for open discussions. Further particulars may be obtained from the secretary of the Associazione, Via S. Paolo, 10, Milano, Italy.

THE LATE MR. C. F. MUNDAY, C.B.—The death is reported from Bournemouth, where he had been living in retirement, of Mr. Charles Frederick Munday, a former Deputy Director of Naval Construction at the Admiralty. Mr. Munday, who was 80 years of age, was one of the first three entrants, by open competition, in H.M.S. Marlborough, the training ship for "engineer students" at Portsmouth. He served as an Assistant Director of Naval Construction from 1919 to 1924, when he was promoted to Deputy Director, holding that position until his retirement in 1928. He was awarded the C.B. in 1925.

DIESEL LOCOMOTIVES FOR ALGERIA.—Ten 32-ton six-wheel Diesel locomotives are now being delivered from the Leeds works of the Hunslet Engine Company, Limited, to Algeria. They are to be employed to improve the efficiency of industrial shunting and short-distance haulage work in districts where water is absent or impure. They are built to standard gauge for a maximum axle load of 11 tons, and incorporate a Gardner 8L3 engine giving 204 brake horse-power at 1,200 r.p.m., which drives the locomotive through Hunslet transmission comprising a friction clutch, a four-step gearbox, jackshaft and rods. The four speeds in the gearbox give track speeds of 4½, 7½, 11½ and 18 m.p.h., at top engine revolutions, and the maximum tractive effort is 14,500 lb., corresponding to a factor of adhesion of 4·9 : 1. The 40-in. wheels give a wheelbase of 9 ft. 0 in., so that curves of 120 ft. radius can be negotiated.

50-TON LOW-LOADING TRAILER.

MESSRS. R. A. DYSON AND COMPANY, LIMITED, LIVERPOOL.

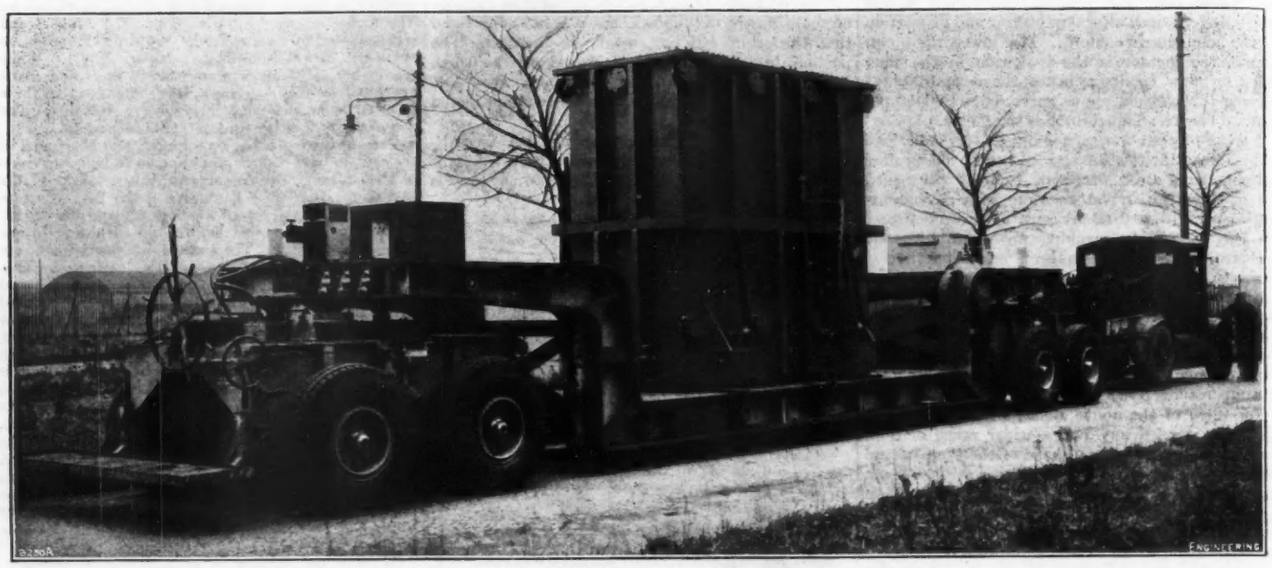


FIG. 1. TRAILER WITH TEST LOAD.

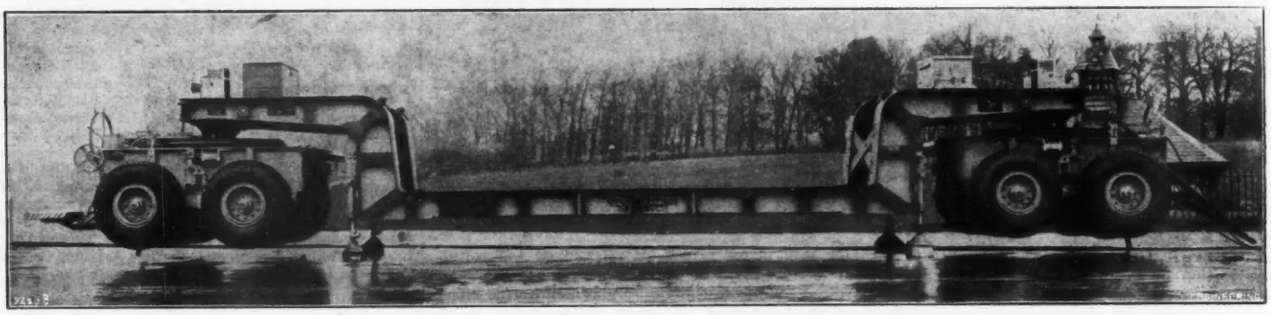


FIG. 2. TRAILER SUPPORTED ON JACKS.

50-TON LOW-LOADING TRAILER.

THE transportation of heavy electrical plant has always been a difficult problem as frequently the load cannot be divided into parts and consequently has to be carried as a complete unit on special road trailers. Messrs. R. A. Dyson and Company, Limited, Grafton-street, Liverpool, have had considerable experience in the design and construction of such trailers, several of which have been described from time to time in ENGINEERING, and recently this firm have completed a trailer for the Government of New Zealand which will be used in that country for the transportation of heavy unit loads in connection with post-war electrification plans. The trailer is illustrated in Figs. 1 and 2, on this page, in Figs. 3 and 4, on the opposite page, and in Figs. 5 to 8, on page 228.

It has been designed to carry a load of 50 tons, which may be concentrated over a length of 5 ft. at the centre, and in Fig. 1 the trailer is shown on test with a load of 42 tons in position; the total weight of trailer and load is 69 tons. In Fig. 2, the trailer is shown raised by four jacks, one at each corner of the dropped portion of the frame; in this position the road wheels are clear of the ground, thus enabling the bogies to be turned through 90 deg., so that when road wheels are lowered the trailer can be moved laterally, which is a useful feature when it is required to move loads into confined spaces. The corner jacks can also be used to raise or lower the trailer platform, so that, within limits, the platform can be brought to the same level as the loading or unloading bay. Furthermore, the bogies have been designed so that they may be detached readily from the frame of the trailer and when it is required to transport the trailer by rail, it is hauled on to a flat railway wagon and, after the latches holding the bogies to the frame have been released, the frame is raised by the four corner jacks, the bogies being wheeled away, and the frame subsequently lowered on to the truck. Another feature of the trailer is that means are provided for increasing the ground clearance from 8 in., which is the normal clearance, to 14 in., so that humpbacked bridges and similar obstructions may be negotiated. In addition, the mechanism by which this is accomplished is arranged so that, when required, three point suspension can be obtained, thus allowing the trailer to cross uneven ground with minimum wracking of the load. The two bogies are identical and both are fitted with steering gear, so that the trailer may be hauled from either end, the draw-frame and steering platform having been designed so that they may be transferred from end to end with comparative ease.

The trailer has an overall length of 49 ft. 3 in., the loading space within the well having a length of 21 ft. 8½ in., while the height from the ground to the floor plates is 2 ft. 1 in. The double-cranked frame, which has a width of 8 ft., is of all-welded construction, and details of the design employed are shown in Figs. 7 and 8, on page 228, which show transverse sections through the centre of the load-carrying platform and the vertical member of one of the swan-necks, respectively. The load-carrying portion of the frame is built with a longitudinal camber of ⅝ in., so that the frame will be horizontal when fully loaded. As will be seen from Fig. 7, the main longitudinals of the frame are fabricated from steel plate built up in the form of an I-beam. The flanges consist of two plates, the inner plates being 16 in. wide by 1 in. thick, while the outer plates are 18 in. wide by 1 in. deep. The inner flange plates, however, do not run the full length of the I-beams, but taper away towards each end, the total length of the plates being 18 ft. The webs, which are 14 in. deep, are made from ½ in. steel plate, and 5 in. by 6 in. T-iron stiffeners are welded at 29½-in. intervals to the web plates and either to the inner or outer flange plates, according to their positions along the frame. The cross members are standard 9 in. by 4 in. I-beams, the top flanges of which have been reinforced by welding on steel plates 8 in. wide by ⅜ in. thick. The cross members are welded to the side members, and additional support is provided at each end by ⅜ in. gusset plates, which are welded to the underside of the cross members and the lower flange plates of the side members. Altogether, nine cross members are fitted to the dropped portion of the frame, the spacing being the same as for the stiffeners, and the centre members, which consist of 8 in. by 4 in. I-beams, are welded directly to the cross members. The load-carrying portion of the frame is covered with sixteen ½-in. chequered-steel plates, all of which are identical in size and jig-drilled, so that they are interchangeable. The construction of the swan-necks and the raised portions of the frame is similar to that for the dropped portion, a transverse section through one of the swan-necks being shown in Fig. 8, on page 228.

As previously mentioned, both bogies are identical and, like the main frame, are of all-welded construction. The side-members consist of I-section girders built up from ½-in. steel plate, the depth being 24 in., and the width of the flanges 6 in. The side members are cut away in the neighbourhood of the axles so as to allow free articulation for the wheels, the depth of the girders at these points being 17 in.; the bottom flanges, however, have been bent into the cut-away portions so that they are continuous throughout their length. Three cross members are fitted, those at the front and rear being standard 8 in. by 3½ in. channel sections, while the centre cross members consist of ½-in. steel web plates, 17 in. deep, to the bottom of which 6 in. by 1 in. flanges are welded. The centre cross members, however, are not fitted with top flanges, as the bogie frames are covered with ½-in. plates and the

50-TON LOW-LOADING TRAILER.

MESSRS. R. A. DYSON AND COMPANY, LIMITED, LIVERPOOL.

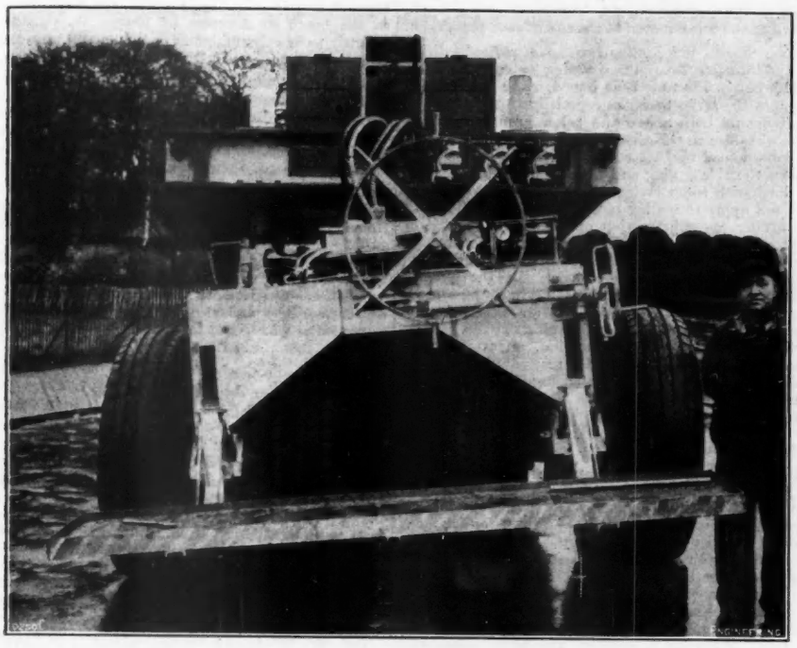
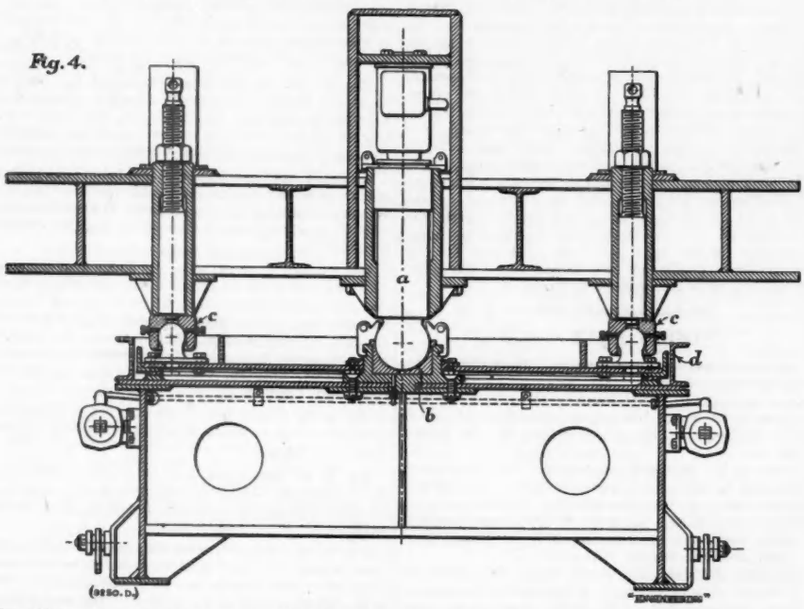


FIG. 3. REAR BOGIE ARRANGED FOR THREE POINT SUSPENSION.

Fig. 4.



webs of the centre cross members are welded directly to this plating. The cover plates are welded to the side and cross members, and are reinforced by triangular-shaped gusset plates which are welded to, and extend forwards and backwards from, the centre cross members. As in the case of the centre cross members, flanges are welded to the lower edges of the gussets and the upper edges are welded directly to the top plating. The wheels are fitted in pairs, each pair having its own axle, and the axles, in turn, are held to the bogies through Woodhead laminated springs fitted with oscillating ends. The axles are secured to the springs by U-bolts fitted with Simmonds lock nuts, and the hubs are carried by Timken taper-roller bearings.

The method by which the bogies are held to the frame is shown in Fig. 4, on this page, which is a transverse sectional elevation through one of the king pins. It will be seen from this illustration that the base of the king pin *a* is in the form of a sphere which mates with a hemispherical cup *b* fitted to the centre of the turntable. The load is transmitted to the bogies through the king pins, the trailer being kept level by the screw jacks *c*; during normal operation, the king pins and screw jacks occupy the positions shown in Fig. 4. The king pins, however, embody hydraulic jacks which, on being pumped down, have the effect of lengthening the king pins and raising the ends of the trailer, thus increasing the ground clearance. When an obstacle which necessitates increased ground clearance has to be negotiated, it is only necessary to pump down the king-pin jacks and re-adjust the screw jacks to make contact with the turntable; by this method the ground clearance can be increased from a minimum of 8 in. to a maximum of 14 in. Obviously, if the screw jacks are not brought into contact with the turntable at one end of the trailer, the frame will be free to oscillate about this end but rigidly supported at the other, thus giving what is virtually three-point suspension. The rear bogie is shown arranged for three-point suspension in Fig. 3, and it will be seen that although the off-side wheels have been raised a considerable distance, in this case approximately 7 in., the main frame of the trailer is level. The hydraulic pressure for actuating the king-pin jacks is supplied by hand-operated hydraulic pumps, there being a separate pump for each king pin; one of the pumps can be seen in Fig. 3 just above the steering wheel. It should be noted that the screw jacks are fitted to the frame of the trailer so that, when the bogies are turned through 90 deg. preparatory to moving the trailer sideways, the stability is not affected.

The bogies are steered by roller chains which lie on the circumference of the channel-section ring lettered *d* in Fig. 4. The chains have an ultimate strength of 49,000 lb. and are actuated by worm-reduction steering boxes, one for each bogie. The steering boxes are operated by large helmsman-type wheels, one of which is visible in Fig. 3, and the reduction ratio is 30 to 1; with both bogies in operation, the diameter of the turning circle is approximately 66 ft. As previously mentioned, the steering platform and the drawbar frame can be transferred from end to end of the trailer with comparative ease; the sockets for the drawbar frame can be seen in Fig. 3.

The 16 wheels of the trailer are fitted with Girling internal-expanding brakes, which expand in cast-iron alloy drums having a diameter of 16½ in. The brakes are operated by compressed air on the Clayton-Dewandre two-line system, which ensures automatic application of the brakes in the event of the trailer breaking away from the tractor. Normally the brakes will be operated by the driver of the tractor, but an emergency hand valve is fitted to each bogie, either of which can apply the brakes on all 16 wheels; in addition, a hand-operated linkage is incorporated in the brake-actuating mechanism for parking. Normally the compressed air for the brakes will be supplied by the tractor, but to enable the trailer to be operated by tractors not equipped with compressed-air braking systems, an air compressor driven by a small petrol engine is fitted to the trailer. The wheels are fitted with 14-in. × 20-in. Dunlop tyres and provision has been made for inflating these by the petrol-driven air compressor. The spare wheel is carried in one of the swan necks and is shown in position in Fig. 8, on page 228; owing to the weight of the combined wheel and tyre, the spare wheel-carrier is arranged so that it may be raised and lowered by hand mechanism.

Before the trailer was delivered, it was handed over to a local haulage contractor, for a series of road tests to be carried out. These tests included the transportation of a transformer to the Liverpool docks, and it was during this run that the photograph reproduced in Fig. 1 was taken. The transformer weighed approximately 42 tons, and with this load, the deflection of the frame, measured at the centre, was ¼ in., the tyre and spring deflection being 1¾ in.; the tyre pressure before the commencement of the run was 95 lb. per square inch. During the tests, no troubles were encountered and the trailer was worked into and out of the docks without difficulty.

INSTITUTE OF METALS.—The Institute of Metals Platinum Medal for 1948 has been awarded to Mr. Robert Crooks Stanley, Chairman and President of the International Nickel Company of Canada, Limited, in recognition of his outstanding services to the non-ferrous metal industries.

THE HOMES FUND OF THE INSTITUTION OF ELECTRICAL ENGINEERS.—We understand that the Homes Fund, which was inaugurated by the Institution of Electrical Engineers during the presidency of Sir Harry Railing, as a memorial to those members who lost their lives during the recent war, has reached nearly half the amount of 50,000*l.* which is required for building the first residential estate. The fund has recently received donations from three electricity-supply companies and the same number of municipal supply undertakings; and the Court of Governors hope that, prior to the vesting day (Monday, April 5, 1948), further contributions, which are permissible under the Electricity Act, 1947, will be received.

INDUSTRIAL DIAMONDS.—The *Diamond Market Report*, for 1947, issued by Messrs. J. K. Smit and Sons, Limited, St. Margaret's House, 57-59, Victoria-street, London, S.W.1, states that before the late war the production of industrial diamonds greatly exceeded the consumption, and, as a result, there existed an accumulation of more than 40 million carats of bort and common industrial diamonds. It is pointed out that this quantity, which is more than six times the annual production at the present time, contributed largely to the victory of the Allied Forces in the war. These reserve stocks of bort, however, have now been entirely consumed, and, at the present time, all that is available are the limited supplies emanating from current production. The report adds that there is great difficulty in meeting the demands of peace-time production.

SOUTH WESTERN ELECTRICITY BOARD.

THE Minister of Fuel and Power has announced further appointments to the South Western Electricity Board, Pulteney-Hotel, Bath; the Board is now constituted as follows. The chairman is Mr. S. F. Steward, C.B.E., M.I.P.E., Director-General of Machine Tools, Ministry of Supply, during the war. The deputy chairman is Mr. H. Midgley, M.Sc. (Eng.), M.I.C.E., M.I.E.E., formerly city electrical engineer and manager, Plymouth Corporation Electricity Supply Department. The other members of the Board comprise Engineer Vice-Admiral Sir John Kingcome, K.C.B., M.I.Mech.E., M.I.N.A., Engineer-in-Chief of the Fleet until 1947; Mr. Frank Forrest, C.B.E., M.I.C.E., M.I.Mech.E., M.I.E.E., chief engineer and manager to Birmingham Corporation Electric Supply Department until his retirement in 1944; Mr. S. H. Payne, ex-Mayor of Taunton and for some 30 years district secretary of the Amalgamated Engineering Union; Mr. G. H. Johnstone, O.B.E., D.L., chairman of the Cornwall County Education Committee; and Mr. A. N. Irens, M.I.E.E., A.F.R.Ae.S., chief electrical engineer of the Bristol Aeroplane Company, Limited.

Among the appointments made to the headquarters executive staff of the Board are those of Mr. G. O. McLean, M.Eng., personal assistant to the managing director of Edmundsons' Electricity Corporation, Limited, who is to be chief engineer; Mr. A. W. Allwood, M.Sc., M.I.E.E., A.M.I.Mech.E., deputy city electrical engineer, Norwich, who is to be deputy chief engineer, and Mr. R. W. Steel, M.I.E.E., engineer and manager, Cheltenham Electricity Supply Department, who is to be chief commercial officer. The sub-area managers designated under the Board are Mr. E. C. Willis, F.C.I.S., general manager, Bristol Corporation Electricity Department, who is to be in charge of sub-area No. 1, based on Bristol; Mr. L. V. Turner, M.I.E.E., electrical engineer, Taunton Corporation Electricity Department, who is to be manager of sub-area No. 2, based on Taunton; Mr. G. T. Garwood, B.Sc. (Eng.), M.I.E.E., engineer and manager to the West Hampshire Electricity Company, Limited, who is to take over sub-area No. 3, based on Exeter; Mr. G. J. Hollyer, M.I.E.E., borough electrical engineer and manager, Torquay Corporation, who is to be in charge of sub-area No. 4, based on Torquay; and Mr. A. C. Owen, M.C., general manager, Cornwall Electric Power Company, who is to be manager of sub-area No. 5, based on Camborne. It is stated that the selection of Torquay as sub-area headquarters is pending the progress of the rebuilding of Plymouth.

INSTITUTION OF METALLURGISTS.—The Council of the Institution of Metallurgists announce that the next examinations for the associateship and licentiateship will begin on Monday, September 6. Particulars regarding fees, and copies of the regulations and other information may be obtained from the Registrar of the Institution, 4, Grosvenor-gardens, London, S.W.1. Candidates should note that they must submit their applications for permission to enter for the examinations by April 1.

THE LATE MR. GRIFFITH BREWER.—We note with regret the death of Mr. Griffith Brewer which occurred at his home, Little Burvale, Hersham, Walton-on-Thames, on March 1. Mr. Brewer, who was a pioneer in aviation, was born in London in 1867 and commenced ballooning in 1891. On the formation of the Royal Aero Club he obtained the No. 5 Aeronaut's Certificate and represented Great Britain in four Gordon Bennett balloon races. These were held in Paris in 1906, in St. Louis, U.S.A., in 1907, in Berlin in 1908 and in Geneva in 1922; in 1908 Mr. Brewer won the International Balloon Competition in England. When Mr. Wilbur Wright came to France in 1908, Mr. Brewer was his first English passenger and, in 1914, he himself learnt to fly at Wright Field, Dayton, Ohio, U.S.A., and piloted his own Moth aeroplane from 1930 to 1938. During the war of 1914-18 he was honorary adviser and lecturer to the Airship and Kite-Balloon Services of the Army and Navy, at Roehampton, and it is interesting to note that his lectures on kite balloons were reprinted for the use of the R.A.F. balloon-barrage personnel after the outbreak of the 1939-1945 war. Mr. Brewer was elected a Fellow of the Royal Aeronautical Society in 1903 and was made an Honorary Fellow some years before the late war. In 1912 he founded the Wilbur Wright Memorial Lecture of the Society and, in 1916, delivered the lecture, choosing as his subject "The Life and Work of Wilbur Wright." He also delivered addresses on the scientific research work of the Wright Brothers at Dearborn, and at the Massachusetts Institute of Technology, U.S.A., in 1938. We believe that it was largely due to Mr. Brewer's efforts that Mr. Orville Wright lent the famous aeroplane on which the first power flights were made at Kitty Hawk, North Carolina, to the Science Museum, South Kensington. Mr. Brewer served as President of the Royal Aeronautical Society during the years 1940-42.

BRITISH STANDARD SPECIFICATIONS.

THE following publications of engineering interest have been issued by the British Standards Institution. Copies are obtainable from the Publications Department of the Institution, 28, Victoria-street, London, S.W.1, at the price quoted at the end of each paragraph.

Cable-Glands and Sealing-Boxes.—A revised edition of Specification No. 542, covering cable-glands and sealing-boxes, has now been issued. The specification is one of the series designed especially to meet colliery requirements both above and below ground, but it is applicable also to other industries. As in the previous editions, issued in 1934 and 1941, the present edition applies to cable sealing and dividing boxes designed to be filled with solid-setting bituminous compound and does not apply to sealing boxes filled with oil. Details concerning the construction of the boxes, as well as methods of jointing, bonding and sealing the cables, are given, together with the recommended minimum sizes of copper rod connections. In the present edition, minimum slip loads, for the grip of the armour clamp, have been prescribed, as an alternative to minimum lengths of armour-clamping surface. As in earlier editions of the specification, no attempt has been made to provide for interchangeability of cable sealing-boxes; this, it is pointed out, must wait until it is possible to standardise the facings upon electrical apparatus in general to which the cable sealing-boxes are required to be attached. [Price 2*s.*, postage included.]

Electricity-Supply Intake Arrangements.—The Codes of Practice Committee for Civil Engineering, Public Works and Building, operating under the ægis of the Ministry of Works, have issued as a draft for comment Code of Practice No. 322.102, which deals with "Electricity-Supply Intake Arrangements for Flats and other Multi-Occupier Buildings." The code, which has been prepared by a committee convened by the Institution of Electrical Engineers, contains recommendations for the installation of rising and lateral electricity conductors. Reference is made to alternative systems of service through an external system of low- or medium-voltage mains or through a transformer substation external to, or installed in a suitable position inside, a building. Particular attention is directed to the questions of location, design and equipment in the case of the transformer substation installed in a building. Details of sizes, types and finishes of vertical ducts or chases required for rising mains are given. Information on the selection of distribution fuse boards and design features allied thereto is provided, and recommended types of lateral conductors, between floor distribution boards and consumers' supply controls, are indicated. Comments on the code received up till Wednesday, March 24, will be examined by the Code and Drafting Committee, and the final draft will be submitted by the Engineering Services Sectional Committee for the approval of the Codes of Practice Committee. [Copies of the Draft Code, reference C P (B) 717, price 2*s.*, postage included.]

BOOKS RECEIVED.

Diesel Operation and Maintenance. By LIEUTENANT-COMMANDER ORVILLE L. ADAMS. Prentice-Hall, Incorporated, 70, Fifth-avenue, New York, U.S.A. [Price 4·70 dols.] Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 28*s.* net.]

Introduction to Electrical Engineering. By PROFESSOR GEORGE V. MUELLER. Second edition. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 5 dols.] McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 30*s.*]

Construction Estimates and Costs. By PROFESSOR H. E. PULVER. Second edition. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 6 dols.] McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 36*s.*]

Selected Techniques of Statistical Analysis for Scientific and Industrial Research, and Production and Management Engineering. By the Statistical Research Group, Columbia University. Edited by CHURCHILL EISENHART and others. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 6 dols.] McGraw-Hill Publishing Company, Limited, Aldwych, London, W.C.2. [Price 36*s.*]

Department of Scientific and Industrial Research. Science at War. By J. G. CROWTHER and R. WIDDINGTON, F.R.S. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 2*s.* 6*d.* net.]

Whitaker's Almanack, 1948. By JOSEPH WHITAKER. J. Whitaker and Sons, Limited, 13, Bedford-square, London, W.C.1. [Prices: 7*s.* 6*d.* net, shorter edition; 12*s.* 6*d.* net, complete edition; and 25*s.* net, library edition.]

PERSONAL.

MAJOR-GENERAL A. D. CAMPBELL, Chief Engineer and Director of Works, Middle East Land Forces, has been appointed Engineer-in-Chief, War Office.

MR. JOHN ALCOCK, joint managing director of the Hunslet Engine Company, Limited, has been appointed to the board of directors of Messrs. W. G. Bagnall, Limited, locomotive designers and builders, Castle Engine Works, Stafford.

MR. J. M. AIRLIE, a councillor and chairman of the Edinburgh Corporation Public Utilities Committee, and MR. R. WATSON MCCRONE, M.C., B.Sc. (Eng.), A.M.I.C.E., a director of British Metal Industries, Limited, have been appointed members of the South Eastern (Scotland) Electricity Board, Edinburgh.

MR. L. G. AXE, B.Sc., M.I.E.E., manager of the transformer sales department, the British Thomson-Houston Company, Limited, relinquished that position on March 1 on taking up an appointment with the British Thomson-Houston Export Company, Limited. MR. G. W. EDGLEY, M.I.E.E., manager for the company in the Leeds district is to become manager of the firm's transformer-sales and also mining departments. He is succeeded as manager of the Leeds district by MR. H. G. HARLOW, B.Sc., A.M.I.E.E.

MR. J. H. FRY, who founded the business of Fry's Metal Foundries, Limited, Tandem Works, Merton Abbey, London, S.W.19, in 1912, is relinquishing the positions of chairman and managing director. MR. P. M. PARISH has been appointed chairman, and MR. G. W. GIBSON, managing director, in succession to Mr. Fry.

PROFESSOR A. M. TYNDALL, D.Sc., F.R.S., is retiring from the Henry Overton Wills Chair of Physics, University of Bristol, at the end of the present session. PROFESSOR N. F. MOTT, M.A., F.R.S., at present Melville Wills Professor of Theoretical Physics, will become Henry Overton Wills Professor of Physics and director of the Wills Laboratory. DR. C. F. POWELL will become Melville Wills Professor and DR. S. H. PIPER, assistant director of the Wills Laboratory.

MR. W. R. BERRY, M.Sc. (Manch.), M.I.Mech.E., F.R.I.C., F.I.M., has relinquished his directorship of Messrs. Ibbotson Brothers, Limited, Sheffield, and also his appointment as chief development engineer to the Woodhead group of companies, and has opened a practice as a consulting engineer and metallurgist, at Grey Garth, Wynmore-avenue, Bramhope, near Leeds.

MR. V. H. F. HOPKINS, M.I.Mech.E., has been appointed general Diesel sales manager to Messrs. C.A.V. Limited, Warple-way, Acton, London, W.3. MR. J. C. H. LOVELOCK, M.I.Mech.E., formerly technical representative, has been appointed service manager to the company.

MR. M. W. SHORTER has been appointed sales manager, MR. C. SPRANG, deputy sales manager, and MR. H. J. WILLETT, assistant sales manager (in the rectifier department), Westinghouse Brake and Signal Company, Limited.

MR. FRASER ROBSON, who, for many years, has been associated with the technical development and sales of the firm's oil coolers, heat exchangers and radiators, has been appointed chief engineer of Serck Radiators, Limited, Warwick-road, Birmingham, 11. MR. A. FOWLER, formerly marine manager with Messrs. Buckley and Taylor, Limited, Oldham, has now joined Serck Radiators, Limited.

DR. E. W. FELL, M.Sc. (Birm.), F.R.I.C., has been appointed senior assistant in metallurgy at Bradford Technical College.

MR. P. F. JONES and MR. C. N. SILVERSIDES have been appointed divisional engineers of the Equipment Division of Specialloid Limited, North Finchley, London, N.12.

MR. G. W. TURNER, who was recently awarded the Associateship of the Central Technical College, Birmingham, has been appointed technical assistant, Wire Mills, Elliott Works, Metals Division, Imperial Chemical Industries, Limited, Birmingham.

MR. R. NICHOLSON PARKINS, B.Sc., has been appointed lecturer in metallurgy at King's College, Newcastle-upon-Tyne.

The UNITED STATES INFORMATION SERVICE, which has been situated for the past two years at 33, Davies-street, London, W.1, is now in the American Embassy building, 1, Grosvenor-square, London, W.1. (Telephone (News Section): GROsvenor 4111, extension 240.) The AMERICAN LIBRARY, which also has been situated at the Davies-street address, has been closed temporarily. It will re-open probably early in April.

MR. L. H. SHORT, M.C., M.I.E.E., M.Inst.T., has been appointed chief of administration of the traction department, the English Electric Company, Limited, Queen's House, Kingsway, London, W.C.2, and will co-ordinate the firm's interests in the fields of railway and road transport. MR. R. H. HOWATT has been appointed sales manager in the company's steam-turbine department.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel.—Regular production from the West of Scotland steelworks is almost entirely dependent on scrap supplies, which remain on a hand-to-mouth delivery basis. The temporary shut-down of three Lanarkshire furnaces a fortnight ago resulted from the acute shortage, and until a more regular supply is available intermittent working will be unavoidable. The third of eight new furnaces which Messrs. Stewarts and Lloyds, Motherwell, intend to install to provide steel for a new tube mill which should be completed later in the year, was kindled experimentally last week, but the scrap outlook for normal production is obscure. Hopes for further immediate tonnages are largely centred on increased collection from the remote areas of the country. Pig-iron outputs have been maintained at recent levels. Steadier progress has been made with the running-in process of the new Colville blast-furnace at Tollcross. The demand for semies has been on an increasing scale, the United States and Canada having recently joined the list of countries inquiring for supplies. Makers are already engaged in arranging the tonnages of steel required to meet commitments under the Denmark agreement, as well as those for Sweden, Finland and the Argentine. Tonnages, of course, are additional to ordinary quotas already allocated. The recent improvement in the supply of semies to re-rollers has been fairly satisfactory, except in the case of billets under 3 in. square and sheet bars. Re-rollable scrap has assisted re-rollers of bars and sections to eke out their supplies of billets, but sheetmakers are having to rely almost entirely on slabs and bars. There has been no slackening in the demand for sheets, especially in the lighter gauges. Extensive orders for tubemakers' products are in hand.

Scottish Coal.—The miners have now resumed work at Priory Colliery; otherwise the pit would have been closed permanently. Although the seams are of first-class quality, repeated labour difficulties rendered the pit one of the uneconomic units in the coalfield. The average output per man-shift has been about 16 cwt., compared with the Divisional figure of about 22 cwt. On receipt of the ultimatum to close the pit unless work were resumed on Monday, March 1, five adjoining collieries were picketed, and 3,000 men joined the strikers at Priory. The reduced production was reflected in supplies to consumers served by Lanarkshire, and deliveries to most users were occasionally below the allocation. Graded fuels were particularly affected, but the sound stock position ensured adequate supplies of fuel for industrial purposes. In the export trade, Swedish loadings constituted the major part of recent activities. Cargoes were also stemmed for Eire and Portugal, one of 3,500 tons for Leixoes from Methil loading this week. Eire buyers continue to be selective. The amount of foreign inquiries indicate a considerable potential trade with overseas buyers, but there are increasing signs that quality and price will have to be competitive.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

Welsh Coal Trade.—The export trade has again provided the feature on the Welsh steam-coal market during the past week. There has been further activity and although outputs have been steadily maintained at the local mines it would appear that the business arranged during the week would be sufficient to absorb almost the whole of the coal that will be allocated for shipment during March. Of particular interest was the receipt of the first order, for some years, for a complete cargo of coal from Brazil. This was for 7,000 tons of bunker descriptions for delivery at Rio de Janeiro. Some limited quantities of Welsh coal have been shipped to Brazil during the past few years with cargoes of patent fuel. This has always been an important market for Welsh coals, the district, in 1938, supplying 437,477 tons out of a total United Kingdom trade with Brazil of 531,316 tons. Allocations made for Portugal for March were greatly in excess of those made for February and a number of orders could not be handled. There were no further developments for Argentina, while trade with France and Eire proceeded along steady lines under the allocations made. Business was arranged for 2,500 tons of anthracite duffs for Belgium. Trade arranged for bunker descriptions for delivery to the foreign bunkering depots included supplies for Port Said, Gibraltar, St. Vincent and Madeira. Operators experienced a brisk demand from the inland market.

Swansea Steel-Sheet Industry.—The market report issued by the Incorporated Swansea Exchange states that, last week, business in tin-plate was steady and firm in tone. Fair numbers of orders were received from home and overseas consumers. In the export market, the strong demand was well maintained and makers disposed of larger quantities. Steel sheets are unchanged, and, although production is at a high level, makers are unable to satisfy the demand. The call for supplies of iron and steel scrap is more insistent and efforts are being made to increase the deliveries.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The supply of coke to the blast-furnaces has been disorganised by the strike in the South Yorkshire coalfield and deliveries of pig-iron have ceased. Finished iron is in very strong request and the demand is in excess of the supply. Heavy steel and engineering departments are very well booked. The Vickers' Works of the English Steel Corporation have completed the first part of an order for 24 hollow-forged high-pressure boiler drums and steam receivers for water-tube boilers for power houses at Pyrmont and Fremantle, Australia. A train load of six, weighing 208 tons in all, has left the works; the largest drum was 37 ft. long and weighed 65 tons. The main contractors are International Combustion, Limited, Derby, who placed the order for the drums with Vickers Works. Every process from the manufacture of the material to the finished drum has been carried out at the Corporation's Sheffield works. Insufficient skilled labour and a dearth of materials are hindrances to full production in many Sheffield works in the light as well as in the heavy industries.

South Yorkshire Coal Trade.—The spread of the strike of shot-firers, who felt they had waited too long for a decision about their claim to higher wages, led to a loss of about 40,000 tons of coal before there was a return to work. This will mean a postponement of some of the arrangements for release of steam coal for shipment abroad, and has emphasised the need for the decision to increase the proportion of opencast coal for home industry and the domestic market. A strike of 1,500 coke-oven workers at 11 South Yorkshire coking plants has deprived over 1,000 Sheffield firms of gas from Monday last. Ten of the largest steel firms in Sheffield were allowed to use 50 per cent. of their normal requirements on condition that they ceased to use gas immediately on instruction from the gas company. Gas was also to be used to permit the continued manufacture of materials already in process.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—Conditions in the North Eastern iron and allied trades continue to improve. The recently-established record outputs are being maintained and the better rail-transport facilities permit increased distribution of tonnage. The better deliveries, especially of finished products, however, still fall short of current requirements. The output of Cleveland ironstone is still very disappointing. The meagre yield continues to necessitate the extensive use of costly foreign ores, imports of which are keeping pace with the demand. On the other hand, supplies of fuel are fairly satisfactory at the foundries and steelworks; the most urgent need is for more scrap.

Foundry and Basic Iron.—Difficulties in handling the unabated demand for larger supplies of pig iron for foundry use are still formidable and there seems little likelihood of an early improvement in the position. Ordinary Cleveland foundry pig has been unobtainable for a considerable time, and the occasional make of a substitute for that commodity is trifling. The tonnage of acceptable classes of pig from other producing centres are inadequate for current needs. Basic-iron blast-furnaces are now turning out tonnage which about meets the essential requirements of the local steel furnaces, but provides no surplus for other uses.

Hematite, Low-Phosphorus and Refined Iron.—East-Coast hematite manufacturers are maintaining deliveries at a level which is sufficient for the current needs of regular consumers, but the persistent demands for parcels for re-stocking purposes are unsuccessful. The outputs of low- and medium-phosphorus grades of iron are going steadily into use and makers of refined iron have no difficulty in clearing their products.

Manufactured Iron and Steel.—Firms providing semi-finished and finished iron have well filled order books and steel producers still have overwhelming delivery obligations. The demand for steel semies is still greater than can be met. Some increase in the deliveries of billets, blooms, slabs and sheet bars is reported, but imports remain at a low level and re-rollers are almost wholly dependent on supplies from home sources. Steel exports from the Tees are much lower than could be desired but are likely to improve considerably during the third quarter of the year. Home deliveries of plates and sections are better than of late. The requirements of constructional engineers and power-plant erectors are exceptionally heavy, and mills producing railway requisites and colliery equipment have a great deal of work in hand.

NOTABLE CONVEYOR BELT.—The Manchester works of the Dunlop Rubber Company, Limited, have completed a conveyor belt nearly a quarter of a mile long and weighing over nine tons. It has been dispatched to the Delco Mines, Sierra Leone.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

INSTITUTE OF TRANSPORT.—Monday, March 8, 5.30 p.m., Institution of Electrical Engineers, Victoria-embankment, W.C.2. "Road Passenger Transport Services," by Mr. D. M. Sinclair. *Yorkshire Section:* Tuesday, March 9, 6.30 p.m., Great Northern Station Hotel, Leeds. "Problems of Air Transport," by Mr. F. N. Hillier. *Hull Centre:* Tuesday, March 9, 7.30 p.m., Chamber of Commerce, Hull. "Transport in a Large Chemical Factory," by Mr. T. C. Mitchell.

INSTITUTION OF ELECTRICAL ENGINEERS.—*North-Eastern Centre:* Monday, March 8, 6.15 p.m., Neville Hall, Newcastle-upon-Tyne. "High-Voltage Transmission by Underground Cables," by Mr. R. N. Berry. *Radio Section:* Tuesday, March 9, 5.30 p.m., Victoria-embankment, W.C.2. "Automatic Telegraphy and Single-Side-Band Working," by Mr. A. Cook. *East Midland Centre:* Tuesday, March 9, 6.30 p.m., Electricity Showrooms, Derby. "Electric Traction on the Southern Railway," by Mr. C. M. Cock. *North Midland Centre:* Tuesday, March 9, 7 p.m., Albert Hall, Leeds. Faraday Lecture, by Dr. P. Dunsheath. *Transmission Section:* Wednesday, March 10, 5.30 p.m., Victoria-embankment, W.C.2. "Behaviour of Cable Accessories in Service," by Messrs. C. J. Armstrong and C. T. W. Sutton. *Western Centre:* Wednesday, March 10, 5 p.m., Merchant Venturers' Technical College, Bristol. "Rectifier Meter for the Measurement of Phase Angles," by Professor G. H. Rawcliffe. *Installations Section:* Thursday, March 11, 5.30 p.m., Victoria-embankment, W.C.2. "Specifications for Flexible Electric Cables," by Mr. W. Bowen.

INSTITUTE OF BRITISH FOUNDRYMEN.—*Sheffield Branch:* Monday, March 8, 7.30 p.m., Royal Victoria Hotel, Sheffield. "Foundry Planning," by Mr. D. A. Chaytor. *Lancashire Branch:* Wednesday, March 10, 7 p.m., Engineers' Club, Manchester. "Foundry Practice in Works Making Marine Propellers, by Messrs. F. J. Tector and J. Martland.

INSTITUTION OF CIVIL ENGINEERS.—Tuesday, March 9, 5.30 p.m., Great George-street, S.W.1. "Photographic Surveying in Relation to Road Engineering in Highly Developed Countries," by Mr. B. F. J. Bradbeer and Professor C. A. Hart. *Birmingham Association:* Thursday, March 11, 6 p.m., James Watt Institute, Birmingham. "Swedish Bridge Construction and the Sando Bridge," by Mr. Sven Klinberg.

INSTITUTE OF MARINE ENGINEERS.—Tuesday, March 9, 5.30 p.m., 85, Minories, E.C.3. "Developments in Marine Reduction Gearing," by Dr. W. A. Tuplin.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—Tuesday, March 9, 6.30 p.m., 39, Elmbank-crescent, Glasgow, C.2. "Shipbuilding Radiography," by Dr. L. Mullins.

ROYAL SOCIETY OF ARTS.—Wednesday, March 10, 2.30 p.m., John Adam-street, W.C.2. "The Trade and Technical Press," by Mr. Roland E. Dangerfield.

NEWCOMEN SOCIETY.—Wednesday, March 10, 5.30 p.m., Institution of Civil Engineers, Great George-street, S.W.1. "Distillation: The Invention of the Rectifying Column," by Professor R. J. Forbes.

INSTITUTION OF LOCOMOTIVE ENGINEERS.—Wednesday, March 10, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, S.W.1. "L.N.E.R. Carriage and Wagon Design, 1923-1941," by Mr. N. Newsome.

JUNIOR INSTITUTION OF ENGINEERS.—*Sheffield Section:* Wednesday, March 10, 7 p.m., Royal Victoria Hotel, Sheffield. Presidential Address, by Mr. R. A. Riddles. *Institution:* Friday, March 12, 6.30 p.m., 39, Victoria-street, S.W.1. "Some Unusual Locomotives," by Mr. C. R. H. Simpson.

SOCIÉTÉ DES INGÉNIEURS CIVILS DE FRANCE (BRITISH SECTION).—Thursday, March 11, 5.30 p.m., Institution of Civil Engineers, Great George-street, S.W.1. Joint Meeting with INSTITUTION OF CIVIL ENGINEERS. "Reconstruction of Road Bridges in France," by Mr. A. Rumpler.

INSTITUTION OF STRUCTURAL ENGINEERS.—Thursday, March 11, 6 p.m., 11, Upper Belgrave-street, S.W.1. "A Comparative Study of Engineering," by Mr. S. J. Crispin.

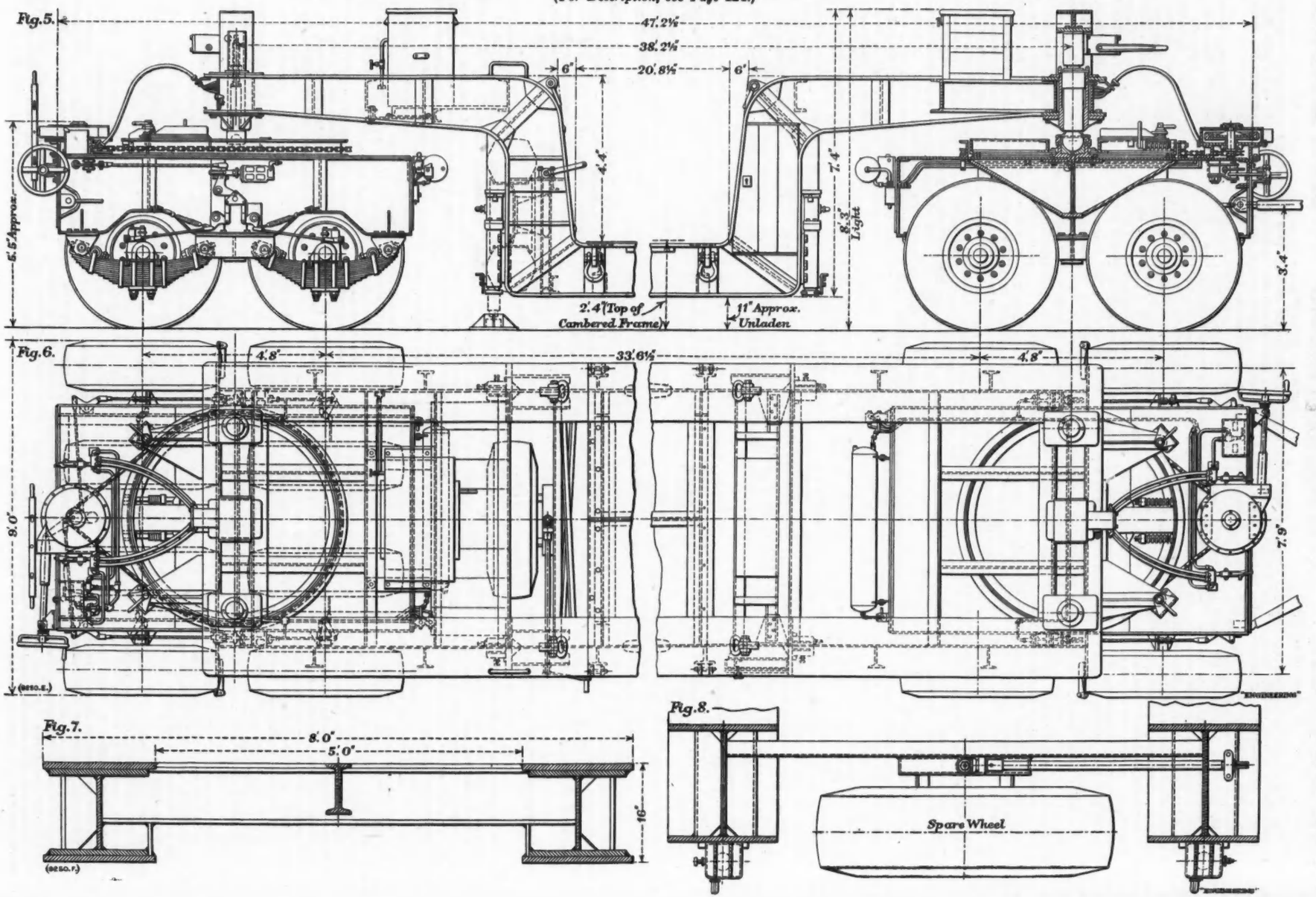
INSTITUTION OF MECHANICAL ENGINEERS.—Friday, March 12, 5.30 p.m., Storey's-gate, S.W.1. Meeting with *Applied Mechanics Group.* "The Criterion of 'Yield' of Gun Steels," by Professor J. L. M. Morrison. "Plastic Stress-Strain Relations," by Dr. W. M. Shepherd.

ROYAL INSTITUTION.—Friday, March 12, 9 p.m., 21, Albemarle-street, W.1. "Lightning and Spark Phenomena," by Dr. T. E. Allibone.

50-TON LOW-LOADING TRAILER.

MESSRS. R. A. DYSON AND COMPANY, LIMITED, LIVERPOOL.

(*For Description, see Page 224.*)



ENGINEERING.

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ADVERTISEMENT RATES.

Terms for displayed advertisements on the green art paper wrapper, on the inside black and white pages and in the buff art paper two-colour supplement, as well as for insets, can be obtained on application to the Manager. The pages are 12 in. deep and 9 in. wide, divisible into four columns 2¼ in. wide. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

The charge for advertisements classified under the headings of "Appointments Open," "Situations Wanted," "Tenders," etc., is 8*s.* for the first four lines or under, and 2*s.* per line up to one inch. The line averages six words and when an advertisement measures an inch or more, the charge is 24*s.* per inch. If use is made of a box number the extra charge is 1*s.* per insertion, with the exception of advertisements appearing under "Situations Wanted." Series discounts for all classified advertisements can be obtained at the following rates:—5 per cent. for six; 12½ per cent. for thirteen; 25 per cent. for twenty-six; and 33⅓ per cent. for fifty-two insertions.

TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be received not later than first post Wednesday.

"Copy" instructions and alterations to standing advertisements for display announcements must be received at least 10 days previous to the date of publication, otherwise it may be impossible to submit proofs for approval.

The Proprietors will not hold themselves responsible for advertisers' blocks left in their possession for more than two years.

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ENGINEERING

FRIDAY, MARCH 5, 1948.

VOL. 165. No. 4284.

TORSIONAL FATIGUE OF MARINE-ENGINE SHAFTING.

ECONOMICAL design in mechanical engineering is essentially a matter of accurately relating the stresses encountered in service to the strength of the material employed. It is characteristic of science, applied to the determination of precise data on which such relations may be based, to reveal that the problem is much more complex than might appear from its simple statement, and that assumptions tacitly or sensibly made may often fall wide of the mark. Such assumptions commonly have to be made, of course, solely through lack of knowledge and not through lack of recognition on the part of the designer, but none the less they entail factors of safety to counteract uncertainty, and a consequent loss of economy in material. Increasingly careful scrutiny is being given, therefore, to many aspects of design that, in the past, have had to be taken for granted, among which one of exceptional interest is the validity of designing full-scale components of large size by values of mechanical properties determined by appropriate tests of small specimens.

The diversity of those factors, and the consequent complexity of the problem, are readily illustrated. The material of the small specimen, for example, while nominally identical with that of the large, may differ in respect of grain size, heat treatment, work-hardening, or other properties acquired during the whole course of metallurgical and mechanical preparation. Even when small specimens are taken from an actual full-sized part, account must be taken of variations in the latter, associated with the disposition of material in the original ingot of a forging and with its subsequent manufacture, as well as of the possible introduction or relief of residual stresses in the small specimens; and when, as is the case more often than not in mechanical design, the critical stresses tend to promote failure by fatigue, the shape of the specimen and the state of its surface as regards roughness are important in relation to the composition of the material and the sequence of machining and finishing operations.

Among mechanical engineering components in which the stresses causing fatigue flaws have often appeared to be significantly less than those deduced from tests upon small specimens, few can suffer service failure with more disastrous consequences, especially in time of war, than the shafts of large marine engines. When, therefore, the Admiralty were considering the use of shafts made of solid-drawn steel tubes, approximately 10 in. outside diameter and 6 in. bore, with welded flanges, it was very properly decided that, before this design was adopted, full-scale fatigue tests should be made to ascertain the true strength under torsional vibration and the effects of stress-concentrating features of shape such as fillets, oil holes and keyways. Equally appropriate was the choice of Dr. S. F. Dorey, C.B.E., to direct the investigation of a subject to which he could bring a wealth of expert knowledge and practical experience. The paper on "Large-scale Torsional Fatigue Testing of Marine Shafting," which he presented on February 13 to the Applied Mechanics Group of the Institution of Mechanical Engineers, covered only the early series of large-scale tests, but it is of outstanding importance for the numerical results given and for the comparison of them with those of tests conducted on specimens ½ in. in diameter at the National Physical Laboratory, as well as being exceptionally interesting in several aspects of the experimental procedure adopted for exciting torsional fatiguing stresses.

The principle of fatigue testing by inducing vibrations at a frequency approaching that of resonance is not new, and is not without difficulties in controlling, within tolerable limits, the amplitude of vibration and the range of stresses depending on it. Nevertheless, the advantages of achieving torsional stresses, adequate to cause fatigue fracture of a shaft of large diameter, at frequencies of probably the same order as those occurring in full-scale service, and thereby of making rapid tests with a relatively very small absorption of power, are weighty enough to warrant a good deal of trouble and ingenuity in securing the close control of stress. This, Dr. Dorey stated, was limited in his present apparatus to ± 1 per cent. at the maximum loading. Similarly, the method of inducing synchronous vibrations mechanically by means of rotating out-of-balance masses is well established, but the gear described in the paper, embodying three pairs of meshed out-of-balance planet wheels, phased so as to combine simultaneous oscillating torque of the shaft under test with balanced radial components of centrifugal force, and all driven at speeds up to 2,500 r.p.m. through a sun wheel by a 30-h.p. motor, merits detailed attention in its present application to a non-rotating test shaft and also in its potential use for superimposing harmonic torsional vibrations in a rotating shaft. Valuable incidental features of the method adopted are that the test-pieces, being only about 2 ft. long, are much cheaper to make than complete shafts, while the bending stresses due to a 4-ton mass firmly fixed at each end are negligible compared with the experimentally-imposed torsion stresses. Perhaps the least satisfactory point in the assembly is the keyway in the thickened central part of the shaft, where the latter is supported in a fixed bearing at the nodal point corresponding to resonance. Vibratory energy has to be transmitted through this bearing from the exciter to the mass at the far end, and, although frettage corrosion and undue damping have not been difficult to overcome, a significant proportion of the shafts tested have failed by cracking at one or both ends of the keyway. Such results are admittedly instructive as regards the strength of keyways, but, if the main purpose is to test the strength of the flange connections near the ends of the shaft, premature failure at the keyway is objectionable.

The experimental procedure, of subjecting the specimen shafts to a succession of 10-million stress cycles at regular increments of stress until failure occurred, was less adversely criticised in the discussion of the paper in London than might have been expected. So long as the eventual failure stress obtained is not markedly affected by prestressing, there is much to commend a procedure which reduces at least sixfold the number of expensive full-scale test pieces required, while reproducing, during each test, a very large number of differing stress cycles, all within the actual fatigue limit. Moreover, the method is convenient for resonant-frequency testing since, if it is not desired to examine the specimen periodically for incipient flaws, the stress range can be increased simply by increasing the speed of the motor which drives the exciter. The testing frequencies are usually on the rising limb of the resonance peak in the vibration stress-

frequency characteristic, so that a relatively small change in exciter frequency produces an appreciable change in the torsional amplitude and the corresponding stress. The magnification of actual stress in the vibrating shaft, compared with that due to the torque imposed by the exciter, exceeded 30 in some of the experiments, and represents a severe tax on the experimenters' ingenuity in exactly predicting the resonance frequency and controlling the speed of excitation.

The combination of high stresses with some increase of frequency caused such marked heating in certain specimens that they had to be cooled by an air fan. In one case, a rise in surface temperature up to 320 deg. F. seems to have accompanied the approach of fatigue failure, but a significant fall in resonance frequency, doubtless due to incipient crack formation, usually provided a more definite indication. Interesting as these phenomena undoubtedly are, the immediate value of the work lies in the stresses at which fatigue failure occurred, which were directly measured by means of wire resistance strain gauges, affixed in pairs at 45 deg. to the longitudinal axis of each test shaft, and recording on a cathode-ray oscillograph. The results show that all the shafts having welded flanges failed by fatigue cracks in the weld, and that the stresses were consistently much lower, despite the care observed in the preparation and welding operations, than those sustained by comparable tubular steel shafts having integrally-forged flanges. A third series of tests, on 6-in. diameter Meehanite cast-iron shafts, failed at about the same torsional stress range as the steel shafts with welded flanges. The numerical values of stress, of the order $\pm$ 8,000 lb. per square inch, are barely half those obtained with forged shafts, and prompt the general conclusion that any marked departure from traditional practice as regards either the material or the method of manufacture of marine shafting must not be undertaken without extreme caution, and, preferably, should await the outcome of further investigation.

The importance of continuing such investigation on the full size is emphasised by the disparity between the failure stresses observed in Dr. Dorey's machine and those, obtained at the National Physical Laboratory, for the reversed torsional-fatigue limit of $\frac{1}{2}$-in. diameter polished specimens cut from some of the large shafts after full-scale test. The small specimens gave consistently higher failing stresses, ranging from 17 per cent., in the case of steel, up to a rather uncertain 100 per cent. in the case of Meehanite. It must be borne in mind, however, that such "size factors," ranging up to 2 in these tests and approaching 4 in some similar researches carried out in Germany during the war, are not simply due to differences of scale, but also include effects of stress concentration associated with the shape and proportions of the shaft-weld fillets and keyway, and perhaps also with the surface finish and the machining operations entailed in producing it. Shape effects are well recognised already and the present experiments confirm them, inasmuch as the characteristic torsional failure cracks, inclined at about 45 deg. to the longitudinal axis of the large shafts, regularly originated where stress concentration would be expected.

It is clear, however, from a reference in the discussion to a specific investigation of scale effect on fatigue endurance, carried out by the Motor Industries Research Association, that increasing size of otherwise similar specimens can lead to reduction of endurance under fatiguing stresses. The magnitude of the effect, in relation to the inherent fatigue endurance, diminishes with increasing size, so that it is more pronounced between two small specimens than between two large ones of the same relative proportions. The underlying reasons are obscure at present and will probably prove to be decidedly complicated when they are eventually revealed. Manifestly, however, they are of sufficient practical importance to warrant a good deal of further research, and it is not unexpected to find that Dr. Dorey is himself developing a machine for testing 3-in. diameter specimens under the condition of cyclic torque superimposed on a considerable mean torque. The results that he obtains with it, as well as to those of further work on full-sized shafts will be awaited with keen interest.

GERMAN OIL PRODUCTION DURING THE WAR.

IN April, 1944, the production of oil from coal by various processes, in Germany, reached a figure equivalent to more than 5,000,000 metric tons a year (one metric ton equals 0·9842 long ton); by August of the same year, output had fallen to 120,000 metric tons per annum. This, from the German point of view, catastrophic reduction was entirely due to the Allied bombing of oil plants and apart from any evidence of results in other fields is, in itself, complete justification for the strategic bombing policy which was adopted. Production never recovered from this setback which was imposed on the industry in less than six months. A diagram, of German origin, which gives curves showing the output of hydrogenation and Fischer-Tropsch plants from the years 1938 to 1945 is reproduced in a recent publication of the Ministry of Fuel and Power.* This shows a steady and regular increase from 1938 to the peak in the spring of 1944. The output curves then fell, in almost vertical lines, to a position in the autumn of that year which corresponds to a smaller output than that of 1938. The diagram carries arrows indicating bombing raids on oil plants and shows that some 90 such raids were carried out up till the end of August.

The report has been drawn up by a committee appointed by the Ministry in November, 1944. It deals with carbonisation; hydrogenation and Fischer-Tropsch synthesis; crude-oil production; and refining. A number of field teams were constituted, the members of which were given military status, and the advancing armies were followed up as quickly as possible, most plants being inspected and the German personnel interrogated, within a few hours of capture. The chairman of the organising committee was Major K. Gordon, C.B.E., M.C., of Imperial Chemical Industries. The report is a valuable document and gives technical details, with many diagrams and drawings, of the various divisions of its subject. This is not to say, however, that the extensive inquiry has revealed remarkable technical or scientific advance. The large development of production "by the hydrogenation process, was purely due to the desire for self-sufficiency, doubtless for war purposes, and was not due to any technical advance beyond the position known before the war." The two matters which are considered to be of greatest interest from the point of view of technical progress were the provision of raw materials for chemical manufacture, particularly by the Fischer process, and the work on lubricating oils.

Germany has only limited supplies of natural petroleum, but, in expectation of a short war, these were initially developed regardless of the future, and the pre-war production of some 50,000 metric tons a month was doubled. It was later realised that this could not be sustained over a long period, and production ultimately settled down to 60,000 metric tons a month. These figures do not include Austria as, owing to difficulties experienced by the field teams in getting into that country, reliable data could not be assembled. Apparently Austrian sources furnished larger supplies of crude oil than German, as it is stated that the two countries together furnished two million metric tons a year. During the major part of the war the main supplies came from Roumania and other occupied territories, which provided seven million tons a year. Natural oil formed an important item in total supplies and was of particular importance for lubricating-oil production which was based mainly on the refining of crude petroleum. Refining capacity was apparently adequate up to the time of intensive bombing, as before the war it had dealt with imported crudes as well as the natural product.

The total rate of oil production in the early part of 1944, expressed as metric tons per annum, was: by hydrogenation, 3,250,000; by Fischer-Tropsch synthesis, 585,000; by refining of German and Austrian petroleum, 1,770,000; by brown and other coal distillation, 945,000; and benzole, 380,000. This gives a total of 6,930,000 metric tons, which, when the production from natural crudes is subtracted, correspond approximately to the 5,000,000 metric tons already quoted. Until the German armies were driven out of Roumania and other Balkan countries by the Russians in 1944, crude oil from the Near East would appear to have constituted the greatest individual contribution to total supplies. The next most important source was the hydrogenation plants. The first commercial installation of this type was that at Leuna, which went into operation in 1927 and had an output of 400,000 metric tons a year before the outbreak of the war. When the Nazi Party came into power, an extensive building programme was embarked upon, and in 1939 the capacity of the plants in production was 1,355,000 metric tons a year. In the course of the war, this figure was raised to 4,000,000 tons, but the greatest recorded rate of production was 3,250,000 tons a year. The hydrogenation plants were big units with capacities ranging from 200,000 tons to 700,000 tons a year.

Practically the whole of the German aviation spirit production, of some two million metric tons a year, was derived from hydrogenation plants, but these installations also produced fuel and Diesel oils and motor spirit. The yield depended on the raw material, the product and the pressure at which the plant was operated. The original Leuna plant was designed to operate at a pressure of 200 atmospheres, using brown coal, and for the first bituminous-coal plant, that at Scholven, a pressure of 300 atmospheres was employed. For the latest plants constructed, the pressure was raised to 700 atmospheres. The report expresses doubt whether the additional pressure was economically worth while, but actually economics do not seem to have come into the matter. The yield of aviation spirit from bituminous coal, with an operating pressure of 700 atmospheres, was 50 per cent. of the weight of the coal calculated on an ash- and moisture-free basis. At 300 atmospheres, the corresponding percentage was 48. From brown coal, with 250 atmospheres, the yield of spirit was 40 per cent. The cost of motor petrol obtained from Leuna, operating on very cheap brown coal, was 190 RM. per metric ton, equivalent, at the pre-war rate of exchange, to 12·4*d.* a gallon before providing any margin for profit. This was more than double the cost of imported motor spirit.

The Fischer-Tropsch process was of less importance than hydrogenation and very little extension of output took place during the war. No aviation spirit was made in Fischer plants, but a production of some 270,000 metric tons a year of motor spirit was obtained. It would have been possible to improve the quality of the Fischer petrol by secondary processes, but it was evidently considered that hydrogenation plants were the most advantageous source of aviation petrol. It is stated that the main interest of the Fischer process is in providing raw materials for chemical synthesis. The soft wax produced was converted into synthetic fatty acids by oxidation, the product being used both for the preparation of soap and edible fat. Considerable development took place in the production of olefins, which were used for the manufacture of alcohols. Cracked Fischer products were also used in the important field of lubricating-oil production. The major supplies of lubricating oil were obtained from natural petroleum and a remarkably high proportion of the crude was recovered, but it was natural that much attention should be given to possible alternative sources. For the year 1942, the total supply of lubricating oils amounted to 698,000 metric tons, of which 630,000 tons were obtained by conventional refining methods. Of the total, 64,000 tons were aircraft oils. The synthetic oils, obtained by the polymerisation of olefins and ethylene, were mainly used by the Luftwaffe, a 50:50 mixture with mineral oil being employed. A relatively low quality of lubricating oil, produced by the hydrogenation of tars was used for automobiles and general industrial purposes, and 8,000 tons obtained by olefin polymerisation were supplied for tanks and other army vehicles. Aromatic-paraffin condensation provided 2,000 tons of lubricating oil, which was entirely consumed by the German Navy for Diesel engines.

* *Report on the Petroleum and Synthetic Oil Industry of Germany.* H.M. Stationery Office. [Price 10*s.* net.]

NOTES.

HISTORICAL RECORDS OF THE ELECTRICITY INDUSTRY.

THE coincidence of a new campaign for paper salvage with the passing into public ownership of the electric-power industry of the country, which will take effect on April 1, suggests some doubt regarding the fate of old records and other material which the present managements of the appropriated undertakings may consider to be of no further administrative value. We understand, however, that the British Electricity Authority are particularly desirous that no such records should be destroyed prematurely, and that Lord Citrine, as head of the Authority, is keenly interested personally that anything which may contribute to knowledge of the establishment and growth of the industry should be preserved. It is proposed to form a historical section in the library of the British Electricity Authority and, for this reason, any such unwanted material would be welcomed as an addition to the present nucleus of the collection. If it is desired not to part with originals, the Authority would like to have on record particulars of their nature and location. Parcels and communications should be addressed to the British Electricity Authority, British Electricity House, Great Portland-street, London, W.1, and should be marked "Historical Documents."

MOND NICKEL FELLOWSHIPS.

The committee administering the Mond Nickel Fellowships have awarded the two initial Fellowships under a scheme inaugurated in 1947, and particulars of which were given in ENGINEERING on page 255 of volume 161 (1946). The awards are for the year 1947, and have been made to Mr. L. H. Walker, of Reynolds Tube Company, Limited, and to Mr. D. R. G. Davies, of Richard Thomas and Baldwins, Limited. Mr. Walker intends to study the organisation and economics of light-alloy production and the methods of application of group industrial research. Mr. Davies will investigate the application of statistical methods to plant metallurgical and management problems with particular reference to the steel industry. The committee now invite applications for five Fellowships of the average value of 750*l.* each for 1948. Fellowships will be awarded to selected candidates of British nationality, possessing degree or equivalent qualifications, to enable them to obtain wider experience and additional training in industrial establishments, at home or abroad, to render them more suitable for future employment in senior technical and administrative positions in the British metallurgical industries. Each Fellowship will keep the recipient occupied for one full working year. Applicants, who normally should not be over 35 years of age, will be required to define the programme of training in respect of which they are applying for an award, and will also be asked to give particulars of their education, qualifications and previous career. Further particulars and application forms are obtainable from the secretary, Mond Nickel Fellowships Committee, 4, Grosvenor-gardens, London, S.W.1. Completed application forms must be in the hands of the secretary not later than June 1, 1948.

ELECTRICITY SUPPLY IN SCOTLAND.

The North of Scotland Hydro-Electric Board have published details of Constructional Scheme No. 16. This will utilise the water power of 345 square miles of Ross-shire to generate an annual electrical output of 280,000,000 kWh. The scheme provides for the construction of six dams and four generating stations with an aggregate installed capacity of 60 MW. It will develop the resources of the rivers Conon, Meig, Bran, Glascarnoch and their tributaries, and part of the catchment areas of the rivers Carron and Broom. Provision is also made for raising the level of Loch Fannich (Constructional Scheme No. 3) by 20 ft. in order to increase its storage capacity by about 47 per cent., and the output of the Fannich power station by 3,000,000 kWh per annum. The upper section of this project will consist of a new loch formed in Strath Vaich, where a dam will be built. From there the water will be led to a second reservoir formed in the Glascarnoch valley, while a tunnel, five miles long, will convey the water to a generating station at the head of Loch Luichart. A barrage will be constructed at the outlet of Loch a'Chuilinn in Strath Bran and water will be conveyed thence to Achanalt generating station near Grudie Bridge. A dam, 60 ft. high, will also be built near Curin on the River Meig and water conveyed thence to Loch Luichart, the level of which is to be raised by building a dam at its eastern end. Another tunnel will be driven from the neighbourhood of this dam to Luichart generating station below the junction of the rivers Conon and Meig. A dam which is to be constructed on the Conon at Torr Achilty will have a power station incorporated in its structure.

THE GEOLOGICAL SURVEY.

The 25th annual report of the Geological Survey Board, covering the year 1945, has been issued recently, accompanied by a summary of the work of the Geological Survey and the Museum of Geology during the war years 1939-44. Of the work done in 1945, an important part has been the investigation of coal measures suitable for opencast working, but surveys of ironstone deposits and of water supplies have also occupied considerable attention. In the autumn of 1939, a survey was begun of the ironstones in the region between the Humber and Oxfordshire, especially the important beds in Northamptonshire. It is stated that the proved and provable reserves were estimated to amount to more than 2,300 million tons, with additional possible reserves of a further 838 million tons. At the rate of output achieved in 1938, it is considered that these reserves would last for about 340 years. A full report on the ironstone survey is now in draft and will be published in due course. North of the Humber, the Cleveland ironstone beds were re-examined and the conclusion was reached that these might amount to 370 million tons, though it is not certain that the whole of this reserve would be workable. Other minerals investigated during the war, with a view to restricting the dependence of the country on supplies from overseas, were barytes, mainly in the North Pennines; zinc, from the waste dumps in the Alston neighbourhood—where it was found worth while to erect a treatment plant with a capacity of 1,000 tons a day; lead, from the Lake District; potash feldspar, in South Harris; and mica, deposits of which were worked in the Highlands.

RESTRICTIONS OF ELECTRICITY SUPPLY.

As recorded on page 184, *ante*, the Minister of Fuel and Power recently made two Orders dealing with electricity supply. The first of these (S.I. 1948, No. 224) laid down that no undertaking might reduce its prices below those ruling at the date of the Order (February 13, 1948), while the second (S.I. 1948, No. 223) relieved undertakings of the obligation to supply any premises that were not connected to the mains on that date. On Wednesday, February 25, a motion to annul the first of these orders was brought forward by Mr. J. A. Boyd-Carpenter, mainly on the grounds that the practice which it was intended to prevent was indulged in only by municipal undertakings and that privately-owned undertakings should not, therefore, have to suffer any stigma. He also made great play of the fact that the Government, on the one hand, was appealing for a general reduction in prices; and, on the other, preventing the electricity undertakings from taking steps towards that end. The Parliamentary Secretary to the Ministry of Fuel and Power (Mr. Alfred Robens, M.P.), however, speedily disposed of both these points. It was not easy, he said, to distinguish between the two types of undertakings in an Order. He also implied that, if the companies were as innocent as Mr. Boyd Carpenter thought, they had nothing to fear. He further argued that an Order of this kind was necessary to prevent such dissipation of assets as had occurred at Exeter, where 30,000*l.* had been taken out of electricity supply reserve to relieve the rates. It was not, however, intended to affect normal legitimate rebates, but simply to prevent the dissipation of assets. It would be revoked on April 1, when the British Electricity Authority took over. The case against the second Order was presented by Colonel O. E. Crosthwaite-Eyre, who complained that it deprived both domestic and industrial consumers of all the privileges they possessed under existing legislation. In reply, the Parliamentary Secretary agreed that in normal times the obligation of an electricity undertaking to supply a would-be consumer was a safeguard against monopoly abuse. At the present time, however, generating plant was short. In the national interest, therefore, some distinction must be made between the different classes of prospective consumers, and undertakings must not be placed in the ridiculous position of being physically incapable of carrying out a statutory obligation.

ART AND THE INDUSTRIAL REVOLUTION.

On page 76, *ante*, we reviewed Dr. F. D. Klingender's book, *Art and the Industrial Revolution*, in which the author surveys, with copious illustrations, the pictorial and other artistic records of the period from 1760 to the Great Exhibition of 1851 and the influence of the industrial developments of that period upon the means and the manner of artistic expression. On Tuesday, March 2, Dr. H. Shaw, the Director of the Science Museum, South Kensington, opened an exhibition of the original prints, paintings, etc., on which the book was based. The exhibition has been arranged in Heal's Mansard Gallery, 196, Tottenham Court-road, London, W.1, under the direction of Dr. Klingender and in collaboration with the Newcomen Society, whose President, Dr. A. P. Thurston, took the chair at the opening ceremony. In addition to exhibits from Dr. Klingender's and other private collections, there are models, etc., from the Science Museum and the Victoria and Albert Museum, the former including Richard Trevithick's original model road locomotive and the conjectural reconstruction of his locomotive, which was made some years ago by the late Mr. W. W. Mason after an extensive study of the available evidence. The exhibition will be open daily from 9 a.m. to 5.30 p.m. (Saturdays 1 p.m.) until April 13.

"ELECTRICITY AND EVERYMAN."

The Faraday Lecture of the Institution of Electrical Engineers, bearing the title of "Electricity and Everyman," was delivered by Dr. P. Dunsheath, C.B.E., at the Central Hall, Westminster, London, S.W.1, on Friday, February 27, the President (Mr. P. Good) being in the chair. The primary object of this lecture, which is given during the session, not only in London but at a number of centres in the provinces, is to increase the interest of the general public in electrical matters and to illustrate basic principles by typical examples drawn from common practice. A convenient method of making a rapid survey of the uses of electricity, the lecturer said, was to trace the frequencies employed. At one end was static electricity. This was one of the earliest forms to be observed and was still one of the important modern applications. The first step from static electricity was to direct-current, which was employed in a number of manufacturing processes and in internal-combustion engines. Passing to alternating-current it was natural to start at the lower frequencies. The generation and distribution of electric power was carried out at 50 cycles per second and other applications, which the lecturer demonstrated, were the ripple control of street lighting and the operation of gun turrets through appropriate servo-mechanisms. An increase of the frequency some 30 or 40 times brought us into the audio range where the vast field of telephony opened up. In dealing with applications in this field the lecturer referred to a number of important pieces of apparatus, and in particular described the cathode-ray tube which, he said, through television, was becoming a common plaything. By it speech could be made visual, pictures transmitted over long distances and a wide range of other applications opened up. At still higher frequencies electricity could be utilised for the heating of metals and insulators, and was employed for many medical purposes, including diathermy. As the frequency range was again raised we came to the radio field where the energy actually left the conductor. This, however, was too wide a field to be dealt with in one lecture although one of its important uses was illustrated by a demonstration of the radiosonde.

THE ENGINEERING OUTLOOK.

X.—THE AIRCRAFT INDUSTRY.

THE chief problem that the British aircraft industry had to face during 1947 became manifest as soon as the production of military aircraft began to decline, early in 1944. Basically, it is the problem of an industry in which overhead costs have become so high in relation to turnover that it can no longer market its products without incurring crippling losses. Some figures given below show that the cost of prototype development, even of a small passenger aircraft, cannot successfully be borne by a private manufacturing concern, however large; for example, the cost of developing a large civil air liner is unlikely to be less than 3*l.* million, exclusive of the cost of basic research essential to the development of new ideas. It is clear, therefore, that, if the Government's policy is to maintain research and development facilities, and to continue the developments, they must bear a large part of the cost. The extent of the outlay involved was revealed in a statement by the Minister of Supply on November 10, which indicated that the approximate cost of the three prototypes of Britain's largest airliners, including maintenance workshops, hangars and runways, then amounted to 7·2*l.* million, consisting of 5·75*l.* million for the Brabazon I, 800,000*l.* for the DH.106, and 650,000*l.* for the SR.45. The Brabazon is expected to be in service in 1950 and the other two in 1952, and further considerable costs will doubtless be incurred before the completion of the final prototypes.

There was activity on the research and development side of the industry throughout 1947, many new types being publicly tested for the first time, and several put into production. One of the main tasks of the industry has been to develop transport aircraft and civil air-liners to equip British operating companies. The American industry has the considerable advantage of having supplied this type of aircraft in large quantities during the war while the British industry concentrated on fighters and bombers. There remains considerable leeway to be made up, and the mistakes which received so much publicity during the past year were largely the result of insufficient experience.

The extensive public discussion of the disputes between the three air-line corporations, the aircraft manufacturers and the Government does not appear to have brought out very clearly the main causes, which have their roots in the complex machinery used by the Government to administer the industry through the Ministry of Supply, and the users through the Air Ministry and the Ministry of Civil Aviation. The Ministry of Supply are responsible for the administration of the aircraft manufacturing industry, including the maintenance of capacity and financing of research. They are also responsible for the placing of orders with individual companies, to the specifications of the eventual users of the aircraft. These are the Royal Air Force authorities, who state their requirements through the Air Ministry; and the civil operating corporations, who state theirs through the Ministry of Civil Aviation. Interdepartmental committees then work out detailed specifications which are communicated to suitable manufacturing companies by the Ministry of Supply, each being invited to submit tenders. When this has been done, an order for a prototype is placed, again by the Ministry of Supply. It is estimated that about four years normally elapse between the conception of a design and the production of the final prototype, during which time all design modifications by the users pass through the channels outlined above.

This administrative machinery is strongly criticised, both by the manufacturers and by the users, who would prefer to deal with each other directly. It is evident, however, that the requirements of military and civil users—inevitably the concern of separate Government authorities—must be related to available development and manufacturing capacity, and it would appear logical, at first sight, that this task should be entrusted to the department responsible for administration of the manufacturing industry. This worked well enough during the war, when the Ministry of Aircraft Production was the responsible department, but it is evident that the transfer of the main responsibilities for production planning to the manufacturers, which took place after the end of the war, created a new situation with many unsatisfactory features. At the end of September, the Minister of Supply appointed a committee under the chairmanship of Air Chief Marshal Sir Christopher Courtney to inquire into the production of the Tudor I. The committee's findings may well lead to a redistribution of responsibilities. In an interim report, published last January, they recommended that, subject to the original specification performance being realised and a certificate of airworthiness re-issued, Tudor I aircraft should be operated on the London-Montreal service as soon as possible. This, together with a statement by the Government that the three British Corporations would not purchase any more American aircraft, did much to reassure the British aircraft industry. It also emerged from the annual reports of the three Corporations that the only one to show a profit was the British South American Airways Corporation, although they alone operated an all-British fleet of air-liners. This partly discounted reports of the high operating costs and low returns of British Yorks and Lancastrians.

The dispute which arose over the Tudor air-liner reached its climax when this aircraft was rejected by B.O.A.C. in April, 1947. The Tudor I was developed by A. V. Roe and Company, Limited, for use on the North Atlantic route until the new civil types proposed by the Brabazon Committee could take their place. Work was started in the autumn of 1943, and considerable expenses were incurred in the development of the prototype. Shortly after their rejection of the Tudor I, it was rumoured that the British Overseas Airways Corporation were to purchase nine Constellations and six Stratocruisers from the United States; but in July the Ministry of Supply announced that no further imports would be licensed, in order to save dollars and to encourage the British industry.

The only British passenger aircraft built since the war without Government assistance was the 10-seater Cunliffe-Owen Concordia, its design and development costing Cunliffe-Owen Aircraft, Limited, approximately 500,000*l.* This aircraft was far from being a technical failure, and attracted considerable interest during a demonstration flight on the Continent; but the company said that, largely because of exchange difficulties, they were not assured of sufficient sales, and consequently decided to abandon its production. The only manufacturers who can afford to build aircraft privately are the builders of light aircraft; but, even in this field, an informal committee, under the chairmanship of the Director General of Long-Range Planning and Prospects of the Ministry of Civil Aviation, conducted an inquiry in 1947 into the possibility of co-ordinating the technical requirements for six main types.

The Government's most difficult task during 1947 has been undoubtedly that of preserving the manufacturing industry's research, development and building capacity at the highest possible level with the resources made available by the Exchequer. Immediately after the end of the war, the industry was encouraged to fill up surplus capacity with the manufacture of other products, such as aluminium prefabricated houses, household appliances, etc. Certain well-established general engineering firms, such as Vickers Limited, the English Electric Company, and the Hawker-Siddeley Aircraft Company, rapidly switched over to the production of machinery, instruments and other engineering products. Two companies, however, have encountered such difficulties that they have been unable to sustain recurrent and growing losses. Cunliffe-Owen Aircraft, Limited, previously mentioned, wound up their aircraft interests. The Miles Aircraft Company, Limited, were placed in the hands of a receiver last November and remain faced with the threat of compulsory liquidation, although the petition for winding up has been adjourned several times to allow discussion of various possible solutions. In January of this year, an official of the Fairey Aviation Company announced that his firm were interested in the future of the Miles Aircraft Company.

Statements contained in the receiver's report throw considerable light on the difficulties encountered by aircraft manufacturers who have no other engineering interests. The Miles Aircraft Company were this country's largest suppliers of primary-training aircraft during the war, and earned a considerable reputation with their Master and Magister 'planes. During 1946, the company came into preliminary production of civil aircraft, the main types being the Messenger, the Aerovan, and the Gemini, which involved reorganisation, retooling and complete change of layout of the factory. It was not possible to produce any of these aircraft in substantial quantities until 1947. In March of that year, the capital was increased by an issue limited to 1*l.* million of cumulative preferred stock. Considerable losses were incurred, however, particularly through development of several other types of aircraft; for example, the production of the Marathon aircraft, a four-engined passenger machine, did not begin until the end of 1947, and the Merchantman, a four-engined freight 'plane, has not yet come into production. The company's attempts to offset losses on the development and manufacture of aircraft by other activities were on too small a scale and failed to prevent financial collapse. In view of the importance of the types being produced, it is probable that the company's capacity will be preserved, but progress has been too slow to prevent the dispersal of their personnel.

There have been three small new entrants in the industry in 1947. The Essex Aero Company, of Gravesend, are producing a light two-seater aircraft, and Elliotts of Newbury, Limited, who were previously manufacturing several types of sailplanes, produced their first aircraft, the three-seater Eon. Another company, British Messier, Limited, was formed in September last to develop and market aircraft undercarriage, pneumatic and electrical equipment, based on the designs of the Société Messier, of Paris.

The number of persons engaged on aircraft production can only be estimated roughly, as official returns group motor vehicles, aircraft, motor cycles and cycles under one heading. The number employed by these industries at November, 1947, totalled 554,200, compared with 552,400 at June, 1946. It is estimated that the slight increase is accounted for by additions to the motor industry's labour strength and that the numbers employed on the manufacture of aircraft, engines and aircraft components has decreased to a figure somewhere between 150,000 and 200,000. This compares with 815,900 at September, 1945. The only dismissals on a large scale during 1947 were from the Miles Aircraft factories in Reading and Belfast, and from the Cunliffe-Owen factory in Southampton. Further difficulties concerning the upkeep of capacity doubtless will be encountered during the coming year, but, given an adequate supply of materials, there is every reason to believe that the labour force will be maintained at least at its present level.

Factors adversely affecting the production of aircraft during the past year were the fuel crisis during February, and material shortages throughout the year, which, in certain cases, severely limited the output. The most serious shortages of materials were of steel, copper tube, certain types of steel castings, carbon black, and copper enamel wire. The output of A. V. Roe and Company suffered considerable disruptions through the prolonged indecision over the future of the Tudor I, and any similar disputes in the future might well make the already difficult task of maintaining the aircraft industry's war potential even more difficult.

Deliveries of new aircraft in 1947, other than military aircraft for home use, totalled 700, compared with 644 in 1946; and the average monthly structure weight over the year increased from 135 tons in 1946 (the average for January-March, 1946, was 100) to 142 in 1947. In addition, there were 484 conversions of military aircraft to civil types from January, 1945, to November, 1947, of which 200 were effected in 1946, so that the 1947 conversion figure is unlikely to have exceeded that of the previous year. The increase of 9·2 per cent. in deliveries in 1947 is small; but the full weight of the peace-time produc-

tion programme has not yet been felt, and the fuel crisis at the beginning of the year had some adverse effect upon output. In addition, it should be noted that the average structure weight increased by 9·5 per cent. over the 1946 average, implying that large aircraft were being built. The number of complete aircraft manufactured for export in 1947 was 1,758, but it is probable that not more than a third of this number were new, the remainder being used or converted. Among the more important civil deliveries were the Tudor IV's, four of which were delivered to the British South American Airways Corporation during the year, and the Bristol 170, orders for which had totalled 25 (including two prototypes) by August, 1947. Judging by types on order last year, deliveries of many of which should be effected in 1948, the average structure weight should be considerably higher this year than last. Orders included 50 four-engined Miles Marathons, 12 Short Solent flying boats, and the following types of Avro Tudors: Tudor I, two prototypes and 17 production aircraft; Tudor II, two prototypes and 44 production; Tudor III, two production; Tudor IV, four production; and Tudor V and VI, six production each. Details of British Service deliveries are not available, either by number or type, but it is reported that these included several new types of single-engined machines for the Royal Air Force and the Navy, in addition to further Lincoln bombers and Hastings transports.

The annual flying display and exhibition organised by the Society of British Aircraft Constructors was held at Radlett in September and was attended by 10,000 people, including representatives from 45 countries. Seventy new aircraft were exhibited by 28 companies (including de Havilland Aircraft of Canada). Of the 43 aircraft flown, the jet-propelled Attacker, D.H.108, Meteor IV, Vampire, Avro Lancastrian (fitted with two Rolls-Royce Merlin engines and two de Havilland Ghosts), and the Avro Lincoln (fitted with two Merlins and two Bristol Theseus airscrew-turbines) attracted most attention. The static exhibition included the exhibits of 187 manufacturers of engines, components, accessories and materials.

During 1947, many new types of aircraft and engines were officially announced. In April, an Avro Lincoln bomber, powered by two Bristol Theseus airscrew turbines and two Merlin piston engines, made a demonstration flight, the Theseus being the first airscrew-turbine engine in the world to pass official tests. The Armstrong-Whitworth 52 twin-engined jet-propelled "Flying Wing," an experimental aircraft built for the Ministry of Supply for research purposes and said to be the forerunner of the large "flying wing" passenger aircraft of the future, also made its first public flight. Another important prototype, first demonstrated in July, is a flying-boat fighter, the Saunders-Roe A.1, powered by two Metropolitan-Vickers axial-flow jet engines, giving a speed of at least 500 m.p.h.

Two naval fighters, the Westland Wyvern and the Blackburn Firecrest, and one ground fighter, the Spiteful XVI, also made their first public appearance during the past year. The Westland Wyvern is a single-seater torpedo-fighter fitted with a 3,500-h.p. Rolls-Royce Eagle engine, which is the most powerful piston engine made in Britain. The Blackburn Firecrest is powered by a Bristol Centaurus 59 engine; and the Spiteful XVI by a Rolls-Royce Griffon engine, giving it a maximum speed of 494 m.p.h., which is the fastest recorded speed for a piston-engined fighter.

During the past year, several new passenger and freight aircraft, both civil and military, have gone into production, and announcements have been made concerning the planning of the production of further new types. The Handley-Page Hastings, first flown some 18 months ago but only recently shown to the public, is Britain's largest and fastest military transport aeroplane. It can carry 50 fully-equipped airborne troops, or over seven tons of stores when used for supply-dropping, at a maximum speed of 354 m.p.h. Production was also begun during the year of the Vickers Valetta, designed to replace the Dakota as the standard medium transport of the Royal Air Force. The Valetta and the Hastings fill a large gap, previously filled by purchases from the United States, in the production of military transport aircraft. The Valetta will carry 20 paratroops and nine equipment containers. In August, the Tudor VII, with a seating capacity of up to 60 passengers for a range up to 1,000 miles, made its first public flight; its larger size should make it more comfortable than the American Constellation, but its ultimate use has not yet been determined.

The Tudor VIII, powered by four Rolls-Royce Nene engines, is expected to make its first public appearance soon. In October, the Hermes II, a civil development of the Hastings, made its initial flight; it is to be used entirely for research, to provide data on such matters as pressurisation, air-conditioning and soundproofing for the Hermes IV, to be used on the Empire routes of the British Overseas Airways Corporation. During the year, a new four-engined freight carrier was produced by the Miles Aircraft Company; a novel feature of this machine is a detachable freight compartment, approximately 10 ft. long and 4 ft. 6 in. square, which can be fitted with wheels and a towing bar immediately on landing and used as a road trailer. The machine can then be fitted with another container or, if necessary, flown without a freight compartment. Another four-engined Miles freight 'plane, the Merchantman, which made its initial flight during the year, incorporates many of the features of the two-engined Aerovan.

Helicopters have occupied a prominent place in aeronautical news in 1947, and there is every indication that they will continue to do so during the coming year. The first British commercial type, the Bristol Aeroplane Company's Type 171, had its initial tests in the summer; it is intended for use as an air taxi and has accommodation for four passengers, including the pilot. The Fairey Gyrodyne has been undergoing flight tests for some time, but much development and experimental work remains to be done before it goes into production. It is built for four passengers, including the pilot, and will have a maximum speed of 125 m.p.h. A promising helicopter development which may have a very wide application is the telescopic airscrew manufactured by Bevan Brothers, of Rettendon Common, near Chelmsford. The large blade is fitted to a detachable cabin of an aircraft, which can be released through the floor of the fuselage by means of a lever operated by a member of the crew; a 30-ft. blade weighing 60 lb. is said to be sufficient to carry a weight of 1,600 lb., equivalent to six people. After a demonstration of this device, the Air Ministry agreed to provide Halifax bombers for the flying tests. If successful, it would appear to have considerable possibilities as a safety device, particularly in view of the admitted limitations on the use of parachutes from passenger-carrying aircraft.

Further developments of jet-propelled bombers and air-liners are expected to attract attention during the current year. Such developments will require corresponding developments in blind-landing facilities, as the high fuel consumption of turbine-powered aircraft involves adherence to a very strict timetable. Another pre-requisite to their use will be the building of suitable runways and other airport facilities, involving substantial capital expenditure. It is unlikely, however, that the development of turbine-powered long-distance aircraft will outpace the development of suitable airports and landing techniques.

In October, 1947, the Ministry of Supply announced that, 2½ years earlier, an order was placed for a medium-range bomber, powered by two jet engines giving a speed approximately twice that of the current piston-engine bomber, the Avro Lincoln, with a possible speed of approximately 600 miles an hour. In December, the Ministry of Supply ordered the first complete fleet of jet-propelled aircraft, 25 Miles Marathons, powered by two Armstrong-Siddeley Mamba airscrew turbines, delivery of which is expected to begin towards the end of 1948. The finally-developed Airspeed Ambassador is also to be powered by airscrew-turbines, probably either four Napier Naiads or two of the Bristol Proteus type.

Of Britain's three giant aircraft under construction, the Saunders-Roe S.R.45 flying boat, the de Havilland D.H.106, and the Bristol Brabazon I, only the last-mentioned is expected to undergo flight tests this year. These tests will undoubtedly be the principal aeronautical event of 1948. The prototype, which is expected to fly this summer, will be powered by Bristol Centaurus air-cooled radial engines, but all production aircraft are to be fitted with Bristol Proteus airscrew gas turbines.

Since the beginning of this year, there have been three outstanding flying performances by British aircraft. On January 31, Mr. John Cunningham, chief test pilot of the de Havilland Company, flew a Ghost-Vampire to a height of 56,000 ft. on a routine engine-test flight, showing that the Vampire can easily improve on the Italian record of 56,061 ft., although the Ghost was designed expressly for civil transport. On February 6, Squadron-Leader W. A. Waterton claimed a new international speed record for a 100-km. closed circuit when he attained a speed of 542·9 m.p.h. in a Gloster Meteor IV and beat the existing record by 46·02 m.p.h. On February 27, however, this record was broken by Mr. M. J. Lithgow, one of the test pilots of Vickers-Armstrongs Limited. Flying a Supermarine Attacker with a Nene turbo-jet engine, he reached an average speed of 564·8 miles an hour over a 100-km. course.

British exports of aircraft and parts in 1947 totalled 24·8*l.* million. This figure was only exceeded during the three war years 1942-1944 and is nearly five times the highest pre-war figure of 5*l.* million. British exports by countries of destination are only available in respect of complete aircraft for the first ten months of 1947, and are shown in Table I, herewith: Exports to hard-currency areas totalled 4·5*l.* million, accounting for 40·8 per cent. of the total shown in Table I. The two biggest customers were Argentina, with 2·6*l.* million (23·5 per cent.) and Turkey, with 1·6*l.* million (14·6 per cent.). Details of exports by types are not available, apart from those published in the Press. In 1946, Sweden ordered from the de Havilland Aircraft Company a considerable, but undisclosed, number of Vampires, with additional Goblin engines, all of which were delivered within 18 months. A second order, placed in January of this year, is stated to be the largest ever received from abroad by the de Havilland firm for new aircraft and is believed to be one of the largest export orders in the history of the aircraft industry.

TABLE I.—*United Kingdom: Exports of Complete Aircraft by Countries; January to October*, 1947.

Country of Destination.	Value (£1,000).	Percentage of Total.
Canada	43	
United States	1	
Argentina	2,579	
Brazil	83	
Ecuador	78	
Peru	18	
Other American countries	9	
Total, America	2,811	25·6
Sweden	940	
France	622	
Belgium	500	
Eire	457	
Norway	379	
Denmark	325	
Netherlands	319	
Greece	294	
Portugal	257	
Czechoslovakia	173	
Switzerland	120	
Italy	3	
Total, Europe	4,389	39·9
India and Pakistan	654	
South Africa	475	
New Zealand	442	
Australia	23	
Total Other British Dominions	1,594	14·5
Turkey	1,601	
French Indo-China	169	
Java	82	
Iran	73	
Iraq	58	
Ethiopia	53	
Iceland	38	
Syria	27	
Madagascar	23	
Other countries	68	
Total, Other Foreign Countries	2,192	20·0
Total, all countries	10,986	100·0

When the original order was given in 1946, a licence was also granted for the manufacture of the Goblin engine in Sweden, and shortly afterwards some Ghost engines were bought for installation in Swedish aircraft. After a year of extensive trials with a flight of Vampires delivered in the summer of 1946, Switzerland has decided to abandon all other fighters in favour of Vampires and recently ordered 75 Vampires of a modern type, the entire order, including additional turbines and spare parts, totalling approximately 2·25*l.* million. These deliveries may well lead to further orders for other types; it was announced in Berne on May 22, 1947, that Switzerland proposed to maintain a peace-time air force of at least 500 aircraft of the latest type, stating that the greatest progress in jet propulsion had been achieved by the British industry.

Exports to Argentina were known to include some Gloster Meteors, but the main consignment probably consisted of Doves and Vikings ordered in 1946. Most of the aircraft exported to Turkey were believed to be for training purposes. Last September, the Australian Minister for the Navy announced that Australia was to buy 90 modern carrier 'planes from Britain for the Navy's two new aircraft carriers, although no decision had been taken regarding the type to be ordered. In January of this year, A. V. Roe and Company received an order, which exceeded 300,000*l.* in value, from the Royal Afghan Air Force for 12 Anson XVIII aircraft for communication duties, police work and aerial surveying.

The right to manufacture British aircraft engines has been granted to several overseas companies. As already mentioned, the de Havilland Company sold manufacturing rights for their Goblin engine to a Swedish company in 1946. During 1947, the United States Pratt and Whitney Aircraft Division acquired the rights to manufacture the Rolls-Royce Nene engines. Rolls-Royce jet engines are also built under licence in France, by Hispano-Suiza, and in China. In Australia, this year, the Commonwealth Aircraft Corporation of Melbourne will be producing the Rolls-Royce Nene under licence to power Vampires built in the de Havilland works at Sydney. The Concordia, which is not to be produced in this country, may repay some of the 500,000*l.* spent on its design and development if requests received from India and South America to manufacture under licence are granted. Messrs. Rotol, of Gloucester, granted a licence to the Société Anonyme des Ateliers d'Aviation Louis Bréguet, of Paris, to manufacture the Rotol range of airscrews and to market them in France and the French Colonies.

The export results so far achieved by the British aircraft industry are very satisfactory (11*l.* million for complete aircraft in the first ten months of 1947, compared with America's 13·8*l.* million over the same period); and when it is considered that hardly any passenger aircraft of post-war design have been included so far, prospects appear to be very good. A great asset to the export drive in the next few years will be Britain's acknowledged superiority in the field of airscrew turbines and straight-jet engines, to be fitted not only to combat 'planes, but to the first jet-propelled passenger aircraft in the world.

The overseas demand for aircraft is likely to be affected by the availability of suitable currencies. This will probably react strongly in favour of British aircraft, owing to the world dollar shortage. Other factors, such as the unwillingness of overseas Governments to allow import licences for private 'planes, the high operating costs of large passenger machines, and the inability of small State-operated lines to compete with the heavily subsidised British and American services, will doubtless limit the sales of such aircraft. The growing demand for military aircraft from countries such as Sweden, Switzerland, Turkey, China, the Latin-American republics, etc., thrives on political strife, and is likely to be intensified in the future. There will also be a growing market for small utility craft, such as helicopters and the small 'planes suitable for agricultural work, the useful potentialities of which have only begun to be explored.

The large exports of the Viking and Dove are attributable, in part, without detracting from the merits of two very valuable interim machines, to the dollar shortage. The failure to effect sales of the Concordia shows the insecurity of the market for medium passenger 'planes at the present time. Military aircraft are in considerable demand by European countries wishing to rebuild their air-power on modern lines, and by countries which had comparatively small air arms before the war.

Britain's only important competitor is the United States. During 1946, American exports totalled 15·9*l.* million, compared with the British industry's 6·4*l.* million; during 1947, however, the American lead was considerably reduced. American exports

TABLE II.—*United States: Exports of Complete Aircraft in 1946 and from January to October, 1947.*

Country of Destination.	1946. No.	1946. Value (Thousand dols.).	1946. Percentage of Total Value.	January to October, 1947. No.	January to October, 1947. Value (Thousand dols.).	January to October, 1947. Percentage of Total Value.
Argentina ..	341	2,445		522	7,581	
Brazil ..	151	3,707		333	4,055	
Colombia ..	60	1,829		58	748	
Guatemala ..	33	1,004		—	—	
Peru	74	1,120		44	1,181	
Uruguay ..	55	145		63	381	
Venezuela ..	69	4,434		54	1,085	
Mexico ..	439	4,244		211	2,147	
Other Latin American and West Indian countries ..	250	4,571		191	2,939	
Canada ..	340	2,412		378	2,780	
Total, Western Hemisphere ..	1,812	25,911	40·4	1,854	22,897	41·1
Sweden ..	22	2,591		43	219	
Norway ..	4	1,023		16	453	
Switzerland ..	9	726		21	1,539	
France ..	30	10,246		14	3,806	
Belgium ..	47	2,154		73	4,846	
Netherlands ..	34	6,309		12	5,080	
United Kingdom	8	3,719		26	535	
Spain	5	1,365		5	11	
Portugal ..	17	237		40	534	
Total, Europe	176	28,370	44·4	250	17,023	30·6
Australia ..	13	3,981		7	1,832	
South Africa ..	204	1,688		143	2,116	
India	—	—		43	1,031	
Rhodesia ..	2	4		1	65	
Total, British Empire, excluding United Kingdom and Canada	219	5,673	8·8	194	5,044	9·1
China	5	2,500		96	2,489	
Turkey ..	3	495		2	162	
Others ..	28	1,252		139	8,040	
Total, other foreign countries ..	36	4,247	6·6	237	10,691	19·2
Total, all countries ..	2,243	64,201	100·0	2,535	55,655	100·0

of complete aircraft for the first ten months totalled 13·8*l.* million, compared with Britain's 11*l.* million during the same period. On the basis of the figures given above, the yearly rate of American exports in 1947 was about 16·7*l.* million. This was only 5 per cent. more than during 1946, and it would appear that one of the chief reasons for Britain's improved position was the high demand for military fighters.

A study of Table II, herewith, shows that American exports are concentrated on the American continent, which accounted for over 41 per cent. of the total in 1947; Argentina and Brazil were by far the leading customers. Europe accounted for 31 per cent.; British countries, excluding Canada and Britain, for 9 per cent. Exports to "other countries" (the Middle East and Asia, less India) amounted, after only ten months trade, to more than twice their total value during the previous year, while exports to Europe declined by about 40 per cent., reflecting Europe's growing dollar shortage. Of the 535,000 dols. worth of exports to the United Kingdom, 396,000 dols consisted of rotary-wing aircraft, a figure which can be expected to be reduced considerably in 1948 when the production of several types will be under way in this country.

Although none of the major American aircraft firms has gone out of business since the war, most have suffered a greater loss in business than the British makers. Unlike the British companies, the American manufacturers were producing large numbers of medium and large civilian aircraft during the war. In the first two years of peace, there was a sharp decline in the production of commercial machines of five seats and over, in addition to the unavoidable fall in the output of military aircraft (from 47,000 in 1945 to 1,330 in 1946). To aggravate the position still further, the sale of light aircraft, which was expected to offset the fall in demand for other types, declined steadily from the beginning of 1947, forcing manufacturers to cut prices and, in the case of some, to stop production temporarily or permanently. Among the reasons given were the decrease in demand from military training schools, the rising cost of living, (said to be affecting the sale of light private machines) and the slow implementation of the Federal airport programme, which was designed to double the country's 3,000 airports. Nevertheless, the American industry is still operating on a very large scale, although it dropped from its war-time position of being the first United States industry to that of the 14th in 1946. The total business in that year came to approximately a thousand million dollars, of which military aircraft accounted for over 80 per cent. At present, the growing dollar shortage is severely restricting overseas sales and the industry is relying largely on Government military orders to take it over a difficult period.

This reliance on military orders and the importance of having a strong air force was recognised by a Presidential Commission, who issued their report in January of this year. The Commission considered that the present United States Air Force was inadequate for defence even during the period up to 1952, when the United States could be considered comparatively secure from atom-bomb attack, and they recommended that it should be increased from 55 groups to 70 (with 6,869 first-line aircraft); with an Air National Guard of 27 groups and an air reserve of 34 groups. To enable the industry to meet all possible requirements, it was recommended that it should maintain a minimum level of production of 60 million pounds (airframe weight) annually, or exactly twice that recommended by an Air Co-ordinating Committee in October, 1945. The implementation of these recommendations would mean the raising of the present Air Force budget of 2,850 million dols. to 4,150 million dols. for the calendar year 1948, and to 5,450 million dols. in 1949.

Technically, 1947 was not marked by many events of major importance in the United States. One of the most important was the initial flight in October of the 44-ton Northrop Flying Wing, powered by eight General Electric jet engines, which is claimed to be the world's most powerful aircraft; performance figures, however, are not yet available. Another interesting United States achievement during the year was the radio-controlled crossing of the Atlantic by a Douglas Skymaster. British aeronautical circles, however, have expressed the opinion that radio control would only be really practicable and useful when a reliable automatic landing system had been perfected.

The major development in the post-war French aircraft industry has been the production of considerable numbers of four-engined machines of the S.E.161 Languedoc type at the S.N.C.A. factory in Paris. The Languedoc is of entirely French design, but is powered by American engines, and carries 33 passengers at a maximum speed of 320 m.p.h. It is to replace all types in current use on Air France's internal European and African routes, and an order has been placed for 40 machines, most of which have been delivered. Some were also sold to the Polish airline L.O.T., during 1946. Another new French aircraft, seen for the first time in this country last year, was the 72-ton six-engined Latécoère 631, the largest flying boat in Europe until the SR.45 makes its appearance. The Latécoère, like the Languedoc, was designed before the war, primarily to carry 46 passengers with sleeping berths on the North and South Atlantic routes, although over distances up to 1,000 miles it can carry up to 100 passengers. When it visited this country last August, it was powered by six 1,600-h.p. Wright Cyclone engines, which, however, were to

be replaced by more powerful types before it was put into service. They may be used by Air France on their larger services. Mexico was reported to have bought three last year.

Approximately 4,000 aircraft were produced in Czechoslovakia during the war, and the well-equipped modern factories were taken over virtually intact by the Czechoslovak Government in 1945, with the exception of the Aero factory, which had produced about 850 aircraft during the war and was badly damaged by bombing. War-time production figures are probably of little value as a guide to the capacity of the industry, owing to sabotage and obstruction carried out by Czechoslovak labour. At present, labour is in very short supply, particularly the skilled grades, and the production of newly-designed aircraft on a large scale is not yet possible. It has been reported, however, that 15 different types of aircraft are now being built, of which six are derived from German types. In addition, two types of gliders and a helicopter are in production, and a 12-passenger feeder-line aircraft is in the advanced prototype stage.

Sweden, which has built up a modern fighter force since the war comprised largely of Vampires, is to mass-produce a new three-seater monoplane, the SAAB-90 Scandia. Production, planned to be at the rate of six to ten a month, is expected to start this spring, and 70 preliminary orders were reported to have been received by last May. To facilitate the reconstruction of the Dutch aircraft industry, the Fokker Netherlands Associated Aircraft Factories, Incorporated, was formed on February 1, 1947, through the merger of Fokker's Amsterdam factory and the Aviolanda and Scheldt factories. Repairs and reconversions are expected to absorb most of the new company's capacity, before passenger, trainer and military aircraft can be produced.

THE FUTURE ENGINEER.*

By PERCY PARR, B.Sc.

THE title of this address was chosen because it had so many lines of approach. It was something about which we are all interested and even curious, and about which we all have varying views. As, perhaps, the best way of shaping or foretelling the future is by considering the past, it may be well to study the past of the theory and practice of engineering. Originally, there were two types of engineer—the civil engineer and the military engineer; their names accurately and properly described their respective callings. Military engineering was, and still is, engineering as practised in His Majesty's Forces, but there are indications that the same changes which have taken place in civil engineering are also taking place in military engineering. The formation of R.E.M.E. and the mechanisation of the Army, for instance, are signs of a splitting into sub-sections similar to the present-day sub-divisions of civil engineering. Let us hope that this sub-dividing will not follow the haphazard and almost crazy development of the changes in civil engineering.

These latter changes began towards the end of the Nineteenth Century, for, as new fields of engineering were explored and developed, so new branches began to be formed and each new branch brought with it a limitation on the meaning of the term "civil engineering." The formation of these new institutions had many beneficial results, but it also had at least two effects which may be deemed adverse, or, at least, not so desirable. The first was that it produced a crack or division in the structure of civil engineering (not in the Institution of Civil Engineers, but in civilian engineering as a profession). The second was that each new institution provided a new and alluring back door through which many "alphabet chasers" poured with glee.

The current issue of *Whitaker's Almanack* mentions no less than 24 institutions or societies connected with professional civil engineering, and who can say that no more new fields or branches of engineering will be discovered in the future? Dare we hope that the 24 societies will not increase? Is it possible for one institution to be formed to cover all branches of civilian engineering? Let us examine the reasons why new institutions are formed. Is it because some members believe that the parent institution is not in touch with, or cannot adequately cope with the demands of a section of its members; or is it because certain ambitious men wish to take part in the government of an institution and see little hope in the parent institution, and assisted by the alphabet chasers, want a new institution? On the other hand, a new institution may be formed as the result of a genuine keenness for the well being of engineers. Whatever the reason, this policy of splitting into sectional institutions, if it continues in the future at the same rate as it has in the immediate past, will bring such a lowering of status and cheapening of qualifications that, for the majority of engineers, the future will be one of degeneration and uncertainty.

It is obvious that we cannot continue in this way and that a halt must some time be called; in fact, our steps must be retraced if the future is to be worthy of our profession. But by whom shall the halt be called? There is no other answer to this than that the major institutions should foregather and consider what action should be taken, for, in the interests of the profession of engineering, we must have unity: a unity which will see to it that the engineer of the future is provided with the best of training, literature, experience and qualifications. This unity can be achieved only if we civilian engineers are prepared to drop our individuality in our institutions and branches and combine in one professional society capable of covering all activities of civilian engineers. I am confident that if we had the courage to dissolve the scores of subsidiary and sectional institutions now vying with one another for recognition, and to re-constitute those institutions in one comprehensive and corporate body, future years would fully justify our action and any sacrifice of individual status would be amply rewarded.

All of us want the best for the profession, and the foundation of the future structure of civilian engineering must be laid in the training of the engineer. What should this training be? In my early days, the articled pupil became the practical engineer, whereas the university-trained man became the man of theory and was much the inferior to the practical engineer. Of the two methods, I believe the university training was the better, but it lacked a great deal to make it even realistic, quite apart from ideal. The articled-pupil system was based on the assumption that, if left alone, the good engineer was bound to come to the top—and there is a good deal to be said for this system for a very large number of articled pupils became sound and reliable engineers despite of, or perhaps because of, their training. The future demands a casting into the pool of both systems and the evolution of a new system, based upon a new university course of training. The course should be a correctly proportioned and balanced course of theory and practice, with many new subjects, conceived and carried out by both practical and theoretical engineers. I believe that this course can be followed only at a university and that, in future, the main entrance to the civilian engineering profession will be through the portals of a university. There must be, of course, a subsidiary or alternative method of approach for those who by inclination, force of circumstances, or accident are not able to go into a university; but this alternative must be supervised by the university and/or the parent institution, the standard must be high, and it must be made certain that the student misses nothing which will be of value to him in his profession. The Charter of the future should provide that no man or woman be admitted to the profession without adequate qualifications and that these qualifications be obtained in a recognised way and by passing the required examinations; in fact, the abolition of the "back door" and the supervision of all training, which shall be at recognised universities, colleges or schools.

I am emboldened to suggest in greater detail the type and standard of training to be adopted for the future. All students must reach a uniform standard of education—say, that of the Higher School Certificate—and this standard must not be varied by accepting or using any of the institutions' preliminary examinations. All students attending the university must do so for a period of four years, one of which shall be spent with an engineer, but remaining under the supervision of the university. All engineering students must study the same course for, say, two years of their theoretical training, the last year of which must include, in addition to their special subjects, such subjects as advanced administration, report writing, economics, and similar subjects. Immediately following the stay at the university, every engineer must continue for one year under a qualified engineer, to extend his practical experience, and, at the end of that year, on receipt of a certificate of satisfaction, shall be awarded the appropriate degree. This will entitle him to full corporate membership of his institution, and his admission to the profession will be formal. The student who is unable to attend a university must attend an approved technical evening school or correspondence college, work under a qualified engineer for practical experience, and sit and pass the external examination of an approved university. The approved examination shall be the only examination entitling a man to regard himself as qualified to enter and practice the profession of an engineer.

Such a system of training would attract the best men, would be capable of supplying all the requirements of the profession, and would ensure the maintenance of a high standard of competence in the practice of the profession. The settling of a high standard for training will lead the student to demand and expect a high standard of efficiency in looking after his professional needs, and this can only be done by unifying those institutions and societies which claim that such is their business. As a result of this unification, I believe there will be an end of new societies and of some of the more unnecessary institutions, and there will dawn the beginning of a new era for the profession as a whole.

And now, may I point out two of several evils or pitfalls which are still to be avoided if the future is to be what we expect and deserve when we exert all our efforts in becoming competent and qualified engineers? Pitfall No. 1 is the introduction of super-specialisation; a practice which is tending to grow in this country, although its growth is scarcely noticeable as yet. The engineer, perhaps by choice or by accident, when he begins his career, and sometimes even later, is kept on one type of engineering practice—this may be road works, sewer works, reinforced-concrete work or any other section of civilian engineering—and so becomes a super-specialist in his adopted section of the profession. As a result, his outlook is narrowed, his competence, as an engineer, is diminished, and generally quickly falls below the standard set for those in practice. The engineer must be competent and qualified to practise in all the branches of the section of engineering which he has adopted. This pitfall is sometimes varied by making the engineer design the work, but allowing the execution to be carried out by another engineer, or by other persons; and thus the engineer becomes a specialist in design, but does not know anything of those other sections of his work, such as the purchasing of materials, the organisation of the work, and the handling of men and machines. This variation of Pitfall No. 1 is to be avoided at all costs in the future.

Pitfall No. 2, the impact of the Civil Service or Central Government on ordinary life, particularly in local-government service, has had an effect difficult to measure, and might have very serious consequences on the profession. The Central Government is essentially a cumbersome machine, especially designed for a particular job which it certainly carries out effectively. Its every movement, its every action, its every letter, is subject to rules, orders, instructions, minutes and controls, known both inside and outside Central Government offices as "red tape." The effective running of the machine has come to depend on someone who has absorbed and digested all these orders, rules and regulations, and who, without hesitation, can tell immediately what action is prescribed to meet each circumstance.

Herein lies the threat to the status of the professional engineer; for when we consider that, under our system of democratic government, it is possible to place at the head of a department a minister with no personal knowledge or training in the work of that department, and that, therefore, he must obtain almost all guidance and advice from someone who is thoroughly versed in all the details of convention and behaviour, it will be seen how powerful such an expert may become and how he may stand as a barrier between the technical advisor and the Parliamentary minister. As the Central Government encroaches more and more on every-day life, the control of technical matters by the qualified engineer becomes more remote, and the time may not be far distant when departmental policy will be discussed, not with the technical officer of the civil or municipal service, but with the official who is expert only on the regulations of the department.

I have endeavoured to show that the present-day tendency is to create new and separate institutions for every variation in the science of engineering, and that this process of subdivision is not in the best interests of the profession. On the contrary, every effort should be made gradually to eliminate the less important bodies and to merge their activities in a few, and ultimately in one all-embracing institution which would represent every branch of engineering, however novel and however specialised. This single institution, which would be the crowning glory of the profession, would function with the universities and would control the training of students, maintain the standards of efficiency, disseminate the results of the experience and research of engineering in all its branches and, generally, be the authority in all matters concerning the profession of engineer.

* Paper presented to the Northern Counties Branch of the Institution of Structural Engineers, Newcastle-upon-Tyne, on November 19, 1947. Abridged.

H.M.S. "ARTFUL."—H.M. submarine Artful has been accepted into the service of the Royal Navy. Built by Messrs. Scotts' Shipbuilding and Engineering Company, Limited, Greenock, the vessel has a length of 282 ft. and a beam of 22 ft. The main propelling machinery was supplied by Messrs. Peter Brotherhood Limited, Peterborough. The vessel carries seven small guns and four above-water torpedo tubes. Her peace-time complement is five officers and 55 petty officers and ratings.

LAUNCHES AND TRIAL TRIPS.

M.S. "BERGSUND."—Single-screw cargo vessel, specially strengthened for navigation in ice and fitted with telescopic topmasts for passing through the Manchester Ship Canal. Built by the Furness Shipbuilding Company, Limited, Haverton Hill-on-Tees, Co. Durham, for Messrs. Rederi A/B Svea, Stockholm, the vessel is the first of a series of six. Main dimensions: 284 ft. by 39 ft. by 22 ft. 11 in. to shelter deck; deadweight capacity, about 1,800 tons on a draught of 15 ft. 3 in. Six-cylinder "Fiat" Diesel engine of 1,350 brake horsepower, installed by Messrs. Richardsons, Westgarth and Company, Limited, Hartlepool, Sunderland, to provide a service speed of 12½ knots. Launch, February 11.

S.S. "MARNA."—Single-screw cargo vessel built and engined by Messrs. Hall, Russell and Company, Limited, York-place, Aberdeen, to the order of Messrs. Dampskibsselskabet Marna A/S., Oslo, Norway. Main dimensions: 329 ft. by 46 ft. by 28 ft. 6 in. to shelter deck; deadweight capacity, about 3,530 tons on a draught of 18 ft. 7½ in. Fredriksstad four-cylinder double-compound steam motor with two oil-burning boilers. Launch, February 12.

M.S. "GÉNÉRAL GUISAN."—Single-screw vessel for the carriage of grain and general cargoes between European ports and South America, with accommodation for six passengers. Built by Messrs. William Gray and Company, Limited, West Hartlepool, for the Suisse Atlantique Société de Navigation Maritime, S.A., Lausanne, Switzerland. Main dimensions: 420 ft. by 57 ft. 3½ in. by 37 ft. to shelter deck; deadweight capacity, 9,140 tons on a draught of 25 ft. 1 in. Seven-cylinder single-acting Diesel engine of 3,150 brake horse-power, to give a service speed of 12 knots, supplied by Messrs. Sulzer Brothers, Limited, Winterthur, Switzerland, and installed by the Central Marine Engine Works of Messrs. William Gray and Company. Trial trip, February 17.

S.S. "HYALINA."—Single-screw turbo-electric tanker, built by Messrs. Swan, Hunter, and Wigham Richardson, Limited, Wallsend-on-Tyne, for the Anglo-Saxon Petroleum Company, Limited, Great St. Helen's, London, E.C.3. Main dimensions: 550 ft. by 70 ft. by 40ft. 6 in.; deadweight capacity, 18,170 tons on a draught of 31 ft. 7½ in. Two turbo-alternators driving a synchronous-type propelling motor of 13,000 shaft horsepower, supplied by the British Thomson-Houston Company, Limited, Rugby, to give a service speed of 16 knots. Trial trip, February 18.

M.S. "LUCIAN."—Twin-screw cargo vessel, built by Messrs. William Gray and Company, Limited, West Hartlepool, for the United Kingdom to Portugal trade of Messrs. Ellerman and Papayanni Lines, Limited, 22, Water-street, Liverpool. Main dimensions: 255 ft. by 42 ft. by 25 ft. to shelter deck; deadweight capacity, 1,800 tons on a mean draught of 17 ft. Two 960-brake horse-power Polar Diesel engines, supplied by the Atlas Diesel Company, Limited, Beresford-avenue, Wembley, Middlesex, and fitted by the builders' Central Marine Engine Works, to give a speed in service of about 13½ knots. Trial trip, February 20.

M.S. "LEMBULUS."—Single-screw tanker for the carriage of oil and asphalt, built by Messrs. Swan, Hunter, and Wigham Richardson, Limited, Wallsend-on-Tyne, to the order of the Anglo-Saxon Petroleum Company, Limited, Great St. Helen's, London, E.C.3. Main dimensions: 425 ft. by 54 ft. 3 in. by 31 ft.; deadweight capacity, 9,440 tons on a draught of 25 ft. 7½ in. Doxford type three-cylinder opposed-piston two-stroke oil engine of 2,800 brake horse-power, supplied by the Wallsend Slipway and Engineering Company, Limited, Wallsend-on-Tyne, to give a loaded trial speed of 12 knots. Trial trip, February 21.

S.S. "MONGOLIA."—Single-screw cargo vessel, built by Messrs. William Gray and Company, Limited, West Hartlepool, for Messrs. Rederi A/B Arild (J. A. Thore), Arild, Sweden. Main dimensions: 310 ft. by 46 ft. 10 in. by 27 ft. 10½ in. to shelter deck; deadweight capacity, 3,500 tons on a draught of 19 ft. Triple-expansion engines constructed by Messrs. George Clark (1938) Limited, Southwick Engine Works, Sunderland, to provide a service speed of 12 knots. Launch, February 26.

S.S. "PACIFIC FORTUNE."—Single-screw vessel for the carriage of general and refrigerated cargo and edible oil. Accommodation is provided for a limited number of first-class passengers. Built by the Blythswood Shipbuilding Company, Limited, Blythswood Shipyard, Scotstoun, Glasgow, to the order of Messrs. Norfolk and North American Steam Shipping Company, Limited (managers, Messrs. Furness, Withy and Company, Limited, Leadenhall-street, London, E.C.3). Main dimensions: about 500 ft. by 63 ft. 6 in. by 41 ft. to upper deck; deadweight capacity, 11,400 tons on a draught of 29 ft. 6 in. Parsons-type geared turbines and two Yarrow-type water-tube boilers, supplied by Messrs. John Brown and Company, Limited, Clydebank, near Glasgow, giving a speed on trial of about 17½ knots. Trial trip, February 27.

LABOUR NOTES.

SIR STAFFORD CRIPPS, the Chancellor of the Exchequer, stated to a deputation from the staff side of the Civil Service last week that "for reasons given in the White Paper on personal incomes," the Government found it "quite impossible" to apply the principle of equal pay to women civil servants. According to an official statement issued after the interview, he explained to the deputation that the Government wished to re-affirm its acceptance of the principle of paying men and women equally for the same kind of work, but, at the same time, made it clear that in existing economic circumstances, nothing could be done towards putting the principle into practice. He would be ready, however, he added, to reconsider the question "as soon as an improvement in the economic situation arrived." At its meeting in Margate last year, the Labour Party called upon the Government to give effect to the principle.

Under an award of an Industrial Court, the wages of tugboat crews on the Tyne and the Wear have been increased. The crews asked for an increase of 1*l.* a week for all grades of men, and for graded increases for boys giving them 2*l.* 7*s.* 6*d.* a week in their second year, and 2*l.* 17*s.* 6*d.* a week in their third year. The men have been awarded an increase of 7*s.* a week, and the claim of the boys has been conceded in full.

A national agreement covering clerical workers in the British coal-mining industry was signed last week by representatives of the Clerical and Administrative Workers' Union and representatives of the National Coal Board. It affects workers employed in the area, sub-area, and pit offices of the Board, and provides for a working week of 38 hours. Under it, the minimum wage rate rises to 5*l.* a week for male clerks at 21 with further increases up to 6*l.* 10*s.* a week and the minimum rates of women clerks rise to 4*l.* 12*s.* 6*d.* a week with further increases up to 5*l.* 8*s.* a week. Other grades have rates rising to 660*l.* a year for men and to 536*l.* a year for women. The agreement is to have effect as from July 1, 1947.

During the week which ended on February 14 there was a slight reduction in the amount of absenteeism in the coal-mining industry. Voluntary absenteeism by miners at the coal face was 8·07 per cent. compared with 8·12 per cent. in the previous week and 10·45 per cent. in the week which ended on February 15, 1947. The output per man-shift in the week which ended on February 14 was the highest this year; it was 2·91 tons compared with 2·89 tons in the previous week and 2·79 tons in the week which ended on February 15, 1947.

The Minister of Labour and National Service announced last week that Mr. Ness Edwards, M.P., Parliamentary Secretary to the Ministry, and Mr. Harold Boardman, Parliamentary Private Secretary, are to accompany the mission which is to visit the Continent, probably early this month, with the object of recruiting foreign employees for the textile trades. The other members of the mission will be: Mr. C. Henniker-Heaton, Director of the Federation of Master Cotton Spinners' Associations; Mr. Lewis T. Wright and Miss Alice Foley, representing the Northern Counties Textile Trades Federation; Mr. Alfred Roberts, general secretary of the Cardroom Workers' Amalgamation; Mr. Albert Knowles, general secretary of the Operative Spinners' Amalgamation; Mr. E. M. Gray, Director of the Recruitment and Training Department of the Cotton Board; Messrs. H. F. Farrar and F. Hill representing the Wool Textile Employers' Council; and Mr. G. H. Bagnell, general secretary of the National Association of Unions in Textile Trades.

Recently, the Hotels and Restaurants Association and the Residential Hotels Association asked the Ministry of Labour and National Service to postpone the application of the Order made by the Wages Board increasing the wages of a considerable number of their employees after March 4. The Ministry's reply was to the effect that it had no power to postpone the application of the Order.

When a Court of Inquiry awarded the railwaymen's trade unions an advance of 7*s.* 6*d.* a week instead of the 1*l.* a week for which they had asked, it suggested that a new wages structure prepared by the unions was worthy of joint consideration with the Railway Executive. The unions accepted the suggestion, and at the time of writing, negotiations are proceeding on the subject. The main issue is not quite so simple as it looks. If, in the new structure, the wages of the lower-paid employees are increased—as it is believed they will be—those of the higher-paid employees are left practically at their present level—as it is feared in some quarters they will be—there may be trouble over what will, in effect, be abolition of the differentials paid to skilled persons. Much the same may be said of the engineers' proposed new wage structure.

Until the unions affiliated to the Trades Union Congress have reported to the conference of executives which is to be held on March 24, it will be difficult to tell exactly what the reaction of the rank and file is to the General Council's interpretation of the Government's White Paper. A delegate conference of the Transport and General Workers' Union has accepted the advice to the executive council to revise the claims they originally submitted on behalf of London 'bus men. How many others follow the example remains to be seen.

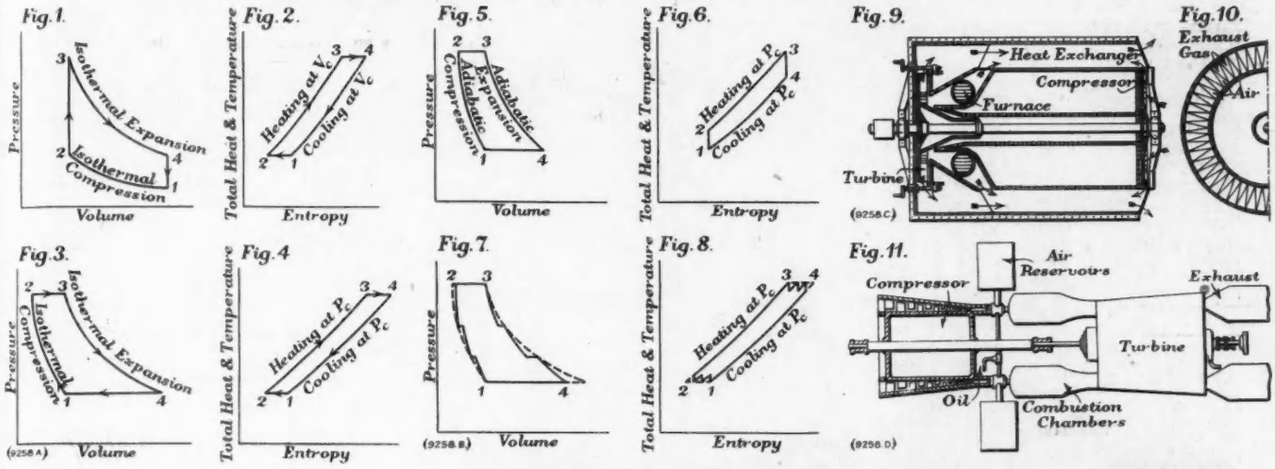
In the course of his introduction to the latest *Monthly Trade Report* of the United Patternmakers' Association, Mr. Beard, the general secretary, says that it is possible that while the sellers' market is here, we may close, or at least greatly reduce, the gap between exports and imports, "but," he continues, "when this sellers' market has passed, and there is competition for the world's markets which, by the way, cannot be long delayed now, what then? Goods not only sell on quality, but on price too, and if goods cannot be sold on price to pay for imports, then only two alternatives are open to us; one is to reduce wages and the other is to increase productive capacity. Failure to do either or both of these things means a slump and wholesale unemployment; that would produce competition for jobs which would ultimately reduce wages at least of those in the competitive industries as it did following World War No. 1."

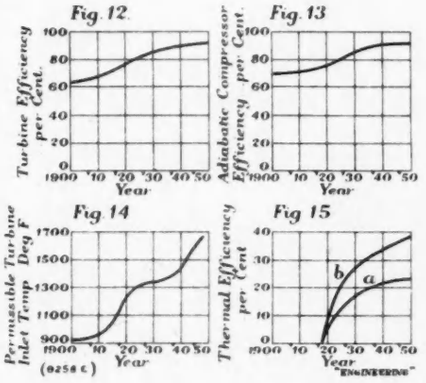
Quoting Sir John Anderson's statement that "some workers are getting higher wages for less production," Mr. Beard says that there "may be some truth in it," "for, obviously," he writes, "a reduction of hours in many industries must mean less production, unless new machinery has been installed to make up the difference. Increases in wages to transport, distributive trades, and other non-productive callings, although not directly competitive, must mean extra costs in the production of engineering, textiles, coal, iron and steel, etc. Where, you may inquire, does a reduction in capital expenditure affect the position? In just this way, that when we have exploited the sellers' market, whether we have closed the gap or not, we will be faced with severe competition from America and elsewhere, and we will, obviously, be unable to compete in price. Indeed, our position may be such that our own people will be unable to afford our own productions, for they will not have the surplus spending power to buy. We must, therefore, increase the productive capacity of all our industries by the introduction of new methods, new machines, and, where possible, complete mechanisation."

According to a joint statement issued on Friday last week by the London Transport Executive and the Transport and General Workers' Union, the wages of London 'busmen are to be increased by 7*s.* 6*d.* a week and their payment for Sunday duty is to be time and a half. The official statement added: "It was further agreed that having regard to the national situation, as set out in the White Paper (on incomes and prices), the union would co-operate with the London Transport Executive in endeavouring to improve the service to the public and secure more efficient operation with the existing staff. This would take the form, firstly of a joint application to the Minister of Transport for the relaxation of the existing rules, so as to enable eight standing passengers to be carried, instead of five, during the permitted hours. Secondly, the staff would work unscheduled overtime when required, to cover sporting, social, and other special events, including the 1948 Olympic Games."

Mr. Martin Lindsay, the Conservative Member for the Solihull Division, asked the Prime Minister in the House of Commons last week whether the Government had revised their policy in regard to the five-day week in view of the urgent need for increased production. Mr. Attlee stated, in reply, that the question of working hours was one which called for determination in accordance with the circumstances of each individual industry. Paragraph 136 of the Economic Survey 1947 (Cmd. 7046) represented the Government's view as to the considerations which should guide the two sides of industry in decisions on the matter.

GAS TURBINES FOR MARINE PROPULSION.





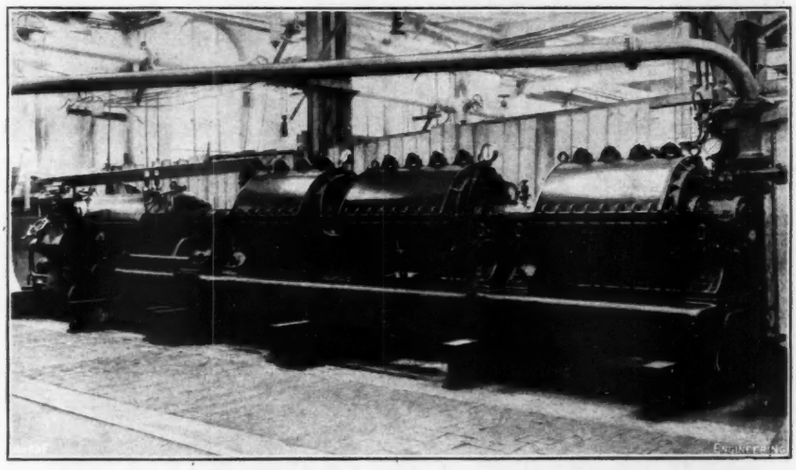


FIG. 16. ARMENGAUD AND LEMALE'S GAS TURBINE, 1905.

THE GAS TURBINE AS APPLIED TO MARINE PROPULSION.*

BY T. A. CROWE, M.Sc., M.I.Mech.E.

THE first patent for a gas turbine was granted in 1791 to John Barber, whose proposals were surprisingly close to modern principles, and included the injection of water into the combustion chamber to cool the products of combustion and augment their volume. In the early part of the Nineteenth Century, Stirling and Ericsson both experimented with hot-air engines, but these were of the reciprocating type and not turbines. It is generally said that the burning-out of the air heaters, which invariably took place in the early hot-air engines, was due to the poor qualities of the materials available, but I feel it was due more to the lack of knowledge of the effect of high gas speeds on the transmission of heat, which allowed the metal forming the heating surfaces to reach a high temperature relative to the final air temperature.

Stirling's engine, which was patented in 1827, was the first to incorporate the regenerator, or heat exchanger, which plays such an important part in modern gas-turbine cycles. In the regenerator, the hot exhaust gases from the engine are used to preheat the compressed air before it enters the air heater proper. In Stirling's engine, this regeneration took place while the air was maintained at a constant volume, so that the pressure increased with the rise of temperature. Regeneration at constant volume can be adopted only in reciprocating engines. It was Ericsson who later suggested that it should take place at constant pressure, a procedure which is suitable for both turbines and reciprocating engines. The pressure-volume and temperature-entropy diagrams for the Stirling cycle are shown in Figs. 1 and 2, respectively, on this page, and for the Ericsson cycle in Figs. 3 and 4. The entropy diagrams for the two cycles differ only in their slopes, a line of constant volume being steeper than a line of constant pressure. Both these cycles have a thermal efficiency equal to the Carnot efficiency, but, as in the Carnot cycle, both involve isothermal compression and expansion which cannot be attained in practice. In actual plants, compression and expansion take place approximately adiabatically, and in 1851 Joule proposed such a cycle, as shown in Figs. 5 and 6, on this page. The Joule cycle is the basic cycle of all constant-pressure gas-turbine plants, and has a lower efficiency than the Carnot cycle operating between the same temperatures. Figs. 7 and 8 show how, by compressing adiabatically in several stages and cooling to the original temperature between each stage, and likewise expanding in stages by intermediate reheating, a closer approach may be made to the Ericsson cycle, and hence to the Carnot efficiency.

In 1861 a patent was granted to M. A. F. Mennons for an open-cycle gas turbine which operated with solid fuel, and incorporated all the principal components of a modern open-cycle unit, including a regenerator. Figs. 9 and 10, on this page, are taken from his patent specification. At the right-hand end of the shaft, a single-stage centrifugal impeller compresses the air and passes it through the inner passages of the regenerator, which is seen more clearly in Fig. 10. The preheated air passes to the furnaces, where solid fuel is burned, and the "dilated" combustion gases pass out radially through the turbine impeller, and then flow back towards the right, through the outer heat-exchanger passages, and are discharged to the atmosphere. Charles G. Curtis took out a patent in the United States, in 1895, for an open-cycle gas turbine using solid, liquid, or gaseous fuel. He advocated the use of a multi-stage axial-flow compressor, a velocity-compounded impulse turbine, and water cooling of the nozzles, rotor, and stator. Fig. 11 shows one arrangement proposed by Curtis, for using oil fuel. The "straight-through" arrangement with a number of combustion chambers is a striking anticipation of some present-day aircraft designs.

In spite of all this early theoretical work, little success was obtained in the practical development of the gas turbine. There were two principal causes for the delay in its development: firstly, the difficulty of obtaining materials which would stand up to the high temperatures, and secondly, the low efficiencies of both compressors and turbines. As a result, the compressors absorbed more power than was developed by the turbine, and therefore power would have had to be supplied to the unit to enable it to run at all. In Figs. 12, 13, and 14, on this page, the various curves give an indication of the improvement in turbine and compressor efficiencies, and the development of heat-resisting metals, during the last few decades, and Fig. 15 shows the overall thermal efficiency, based on these temperatures and efficiencies, of a constant-pressure gas turbine. Curve *a* is for a simple constant-pressure gas turbine without a heat exchanger, and curve *b* is for one with a heat exchanger of 70-per cent. effectiveness. The temperatures used for obtaining the curve shown in Fig. 14, are for a life of 1,000 hours, based on the temperature at which a stress of 3 tons per square inch results in a creep rate of 10^{-8} in. per inch per hour. The curves show that it was only about 1918 that development had advanced to a stage where a gas turbine would give just sufficient power to drive its own compressors. Once this stage had been reached the improvement in efficiency was rapid. These curves are given primarily to emphasise this rapid improvement, but it must not be assumed that the history of the gas turbine can be accurately described by such curves. Some success was obtained before 1918, by adopting various expedients in order to overcome the effects of low machine efficiencies and inadequate strengths of materials. Little was known in the early days about creep of steel at high temperatures, and often gas turbines were run at temperatures which would have resulted in early failure. Sometimes systems were adopted for cooling the blades, or water was injected into the combustion chamber. The 1,000-hour life, on which the curves in Fig. 15 are based, is not considered sufficient for a marine plant, so it must not be assumed that the present-day efficiencies shown in this figure can be obtained in marine installations.

The first large-scale gas turbine to develop sufficient power to drive its own compressor, and still have a

* The Twentieth Thomas Lowe Gray Lecture, delivered to the Institution of Mechanical Engineers, London, on Friday, January 23, 1948. Abridged.

GAS TURBINES FOR MARINE PROPULSION.

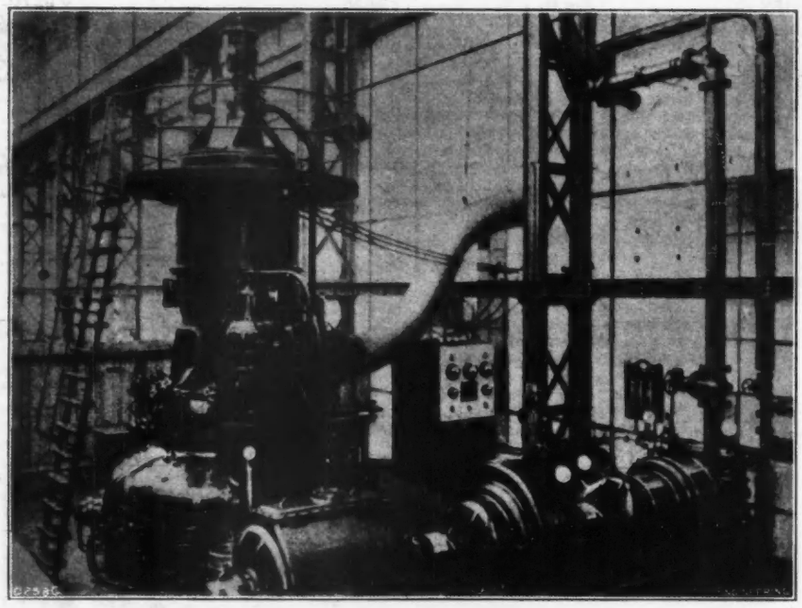


FIG. 17. HOLZWARTH'S GAS TURBINE, 1909-10.

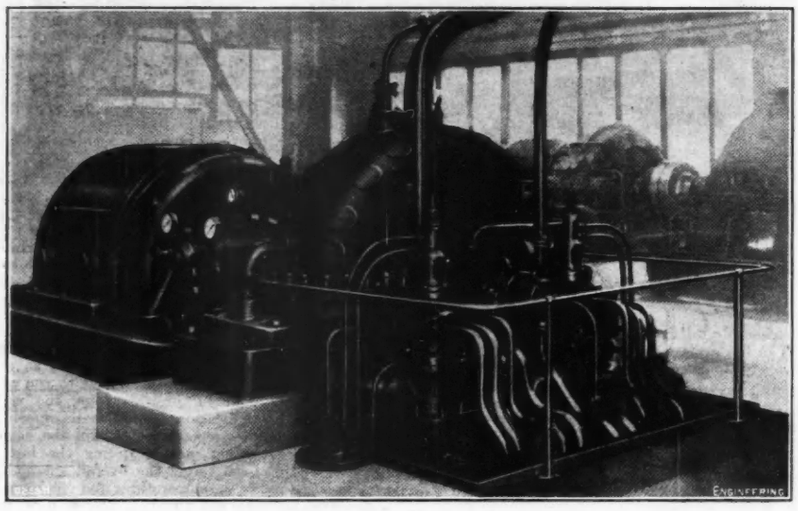


FIG. 18. HOLZWARTH'S GAS TURBINE, 1930-31.

Fig. 19.

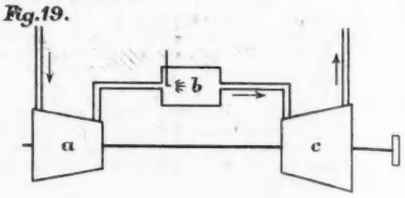


Fig. 20.

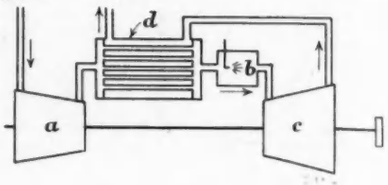


Fig. 21.

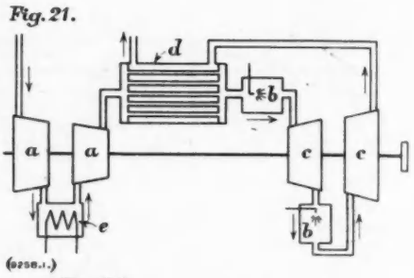
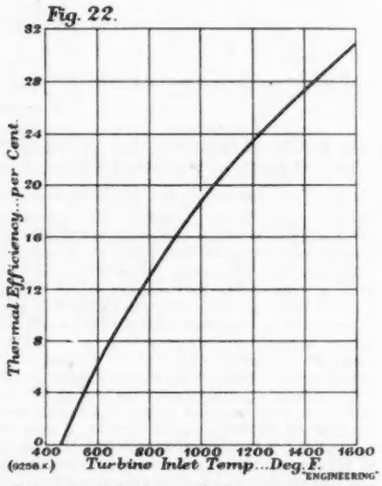


Fig. 22.



margin to do useful work, was that built by the Société des Turbomoteurs, of Paris, about 1905, and is shown in Fig. 16, on page 237. This turbine operated on the constant-pressure cycle, and was designed by Armengaud and Lemale. It consisted of a Curtis wheel, 37·4 in. in diameter, driving a 400-h.p. centrifugal compressor designed by Rateau, with 25 stages in three cylinders, and ran at 4,250 r.p.m. Most of the compressed air was used as combustion and cooling air in the turbine; the remainder was tapped off for use elsewhere, and represented the useful output of the plant. The fuel consumption was approximately 4¾ lb. of oil per effective horse-power per hour, which corresponds to a thermal efficiency of about 3 per cent.

The inefficiency of the early compressors caused the designers of this period to investigate cycles which avoided the use of air compressors. The only cycle to become a practical proposition was the constant-volume cycle developed by Holzwarth, who began experimenting in 1906. In his original turbine, air was taken into the combustion chamber at atmospheric pressure, after which gas was admitted and fired electrically at constant volume, thus raising the pressure to between 70 lb. and 100 lb. per square inch. After ignition had taken place, a valve opened and allowed the gas to pass through the nozzles to the turbine wheel, which consisted of two velocity stages. The combustion chamber, nozzles, and turbine were all water cooled, and the steam generated in the water jackets was used in a separate turbine which drove the scavenging blower. The first Holzwarth gas turbine was built in 1908, by Körting, at Hanover, and was designed for 50 h.p. The second machine was built by Brown Boveri in 1909-10, and is shown in Fig. 17, on this page. It had a vertical shaft and was designed to give an output of 1,000 h.p. This power was never obtained; nevertheless, it may be regarded as the first economically practicable gas turbine.

Much further development was done on the Holzwarth gas turbine, and in later plants the explosive mixture was pre-compressed to about 40 lb. per square inch, whereby the final explosion pressure was raised to about 200 lb. per square inch. Two discharge valves were fitted to the explosion chamber, the second one opening after the first, when the pressure had fallen considerably, and admitting the lower pressure gases to the turbine through a passage which by-passed the first turbine wheel. A 2,000-h.p. unit, shown in Fig. 18, uses blast-furnace gas, and was built by Brown Boveri, and installed in the Thyssen Steel Works, in Hamborn, in 1933. A 5,000-h.p. unit was installed in Germany during the war, but details of this are not available. Although the constant-volume type of gas turbine developed by Holzwarth is attractive, in that it dispenses with the need for an air compressor, the complication of the valve gear and the cooling system and associated steam plant more than outweighs this advantage; to-day, the simpler form of constant-pressure gas turbine is generally preferred.

The simplest form of continuous-combustion, or constant-pressure, gas turbine is shown diagrammatically in Fig. 19, on this page. Its essential features are: an air compressor *a*, which takes in air from the atmosphere and compresses it to a pressure of three or four atmospheres; a combustion chamber *b*, where fuel is burnt, and the air raised to a high temperature at constant pressure; and a turbine *c*, where the gas is expanded down to approximately atmospheric pressure. The thermal efficiency of a turbine working on this simple cycle is naturally low, and varies greatly with the temperatures adopted and with the efficiencies of the turbine and compressor. With present-day material, the thermal efficiency is about 16 to 22 per cent. The pronounced effect of temperature on the thermal efficiency can be seen in Fig. 22, where a curve has been drawn for a simple open-cycle plant with compressor and turbine efficiencies of 85 per cent. and 90 per cent., respectively. The effect of the compressor and turbine efficiencies on the overall efficiency is shown in Fig. 23, opposite. The enclosed shaded area covers the range of machine efficiencies which are necessary in order to obtain any positive

GAS TURBINES FOR MARINE PROPULSION.

Fig. 23.

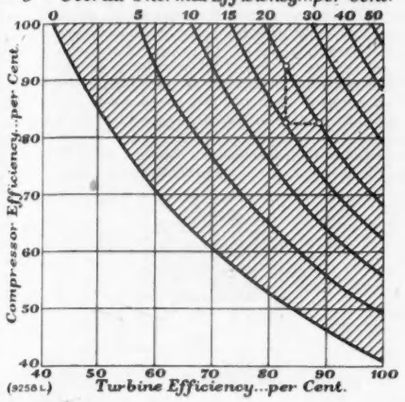


Fig. 24.

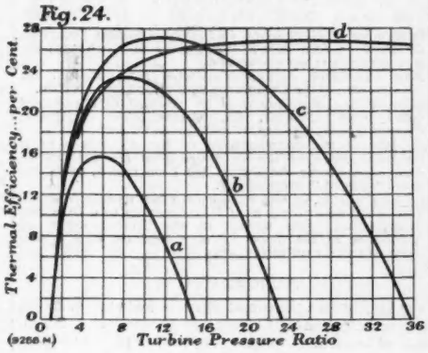


Fig. 25.

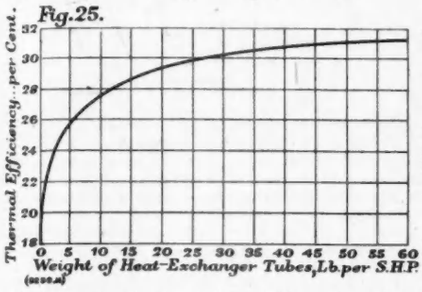
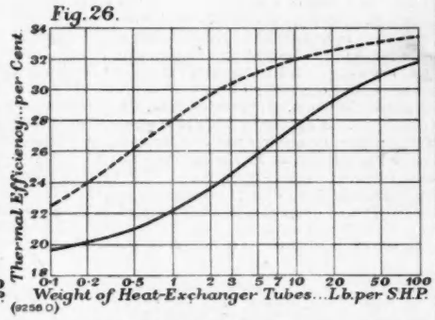


Fig. 26.



output from the plant as a whole. This graph has been based on an air inlet temperature of 60 deg. F., and a maximum turbine inlet temperature of 1,200 deg. F. For a lower turbine inlet temperature, the area of positive power output would be even smaller, and it was the impossibility of reaching this small area with the Nineteenth Century designs of compressor and turbine that resulted in the failure of the early experiments. Fig. 23 also indicates that the overall thermal efficiency is more susceptible to turbine efficiency than to compressor efficiency.

The efficiency of a simple open-cycle gas turbine without heat exchanger also varies greatly with the pressure ratio. This is shown in Fig. 24, on this page, in which the efficiency has been plotted against the pressure ratio for various maximum temperatures and machine efficiencies, which are given in Table I. The

TABLE I.

Curve of Fig. 24.	Turbine Inlet Temperature, deg. F.	Turbine Efficiency, per Cent.	Compressor Efficiency, per Cent.
a	1,200	85	80
b and *d*	1,200	90	85
c	1,400	90	85

curves rise to a maximum at a pressure ratio which depends on the maximum temperature and machine efficiencies, and then fall again to zero at higher ratios. The loss of efficiency at high pressure ratios may appear to be unexpected, but it is explained by the very large temperature changes occurring in the compressor and turbine. With high pressure ratios, the air in the later stages of the compressor becomes so hot that it requires a relatively large amount of work to complete the compression. Similarly, in the turbine, the temperature in the later stages has fallen so much that comparatively little power is developed there. If a heat exchanger is incorporated in the cycle, similar curves will be obtained, although their crests will occur farther to the left; the optimum pressure ratios will be in the region of three to six. It is unlikely, on account of their low efficiency, that gas turbines working on this simple cycle will ever be adopted for marine use, except in small high-speed naval craft, where lightness is a primary consideration and long running periods are not required. They have been successfully utilised, however, for driving stand-by generating units in power stations, where low first cost is more important than low fuel consumption.

The efficiency of a simple constant-pressure gas turbine can be increased by various means. The greatest improvement that can be made is the fitting of a heat exchanger, by which the heat in the exhaust gases can be transferred to the air between the compressor and the combustion chamber. The efficiency can be further improved by compounding the compressor, and intercooling between the stages; and also by compounding the turbine, and reheating between the stages. The effect of such intercooling and reheating is to prevent the excessive temperature changes from occurring in the machines, so that the efficiency does not fall off at large pressure ratios, as already shown in Fig. 24. It is an approach towards the Ericsson cycle (and Carnot efficiency), as already shown in Figs. 7 and 8. A curve, *d*, which represents two stages of compression and expansion, with intercooling and reheating, has also been drawn in Fig. 24, to show the effect of intercooling and reheating. Both curves *b* and *d* are based on the same temperatures and machine efficiencies, so as to give a clear comparison. It will be apparent from Fig. 24, that when compounding the compression and expansion, it will be best to have a larger overall pressure ratio. Thus, in a plant with a heat exchanger and two stages of heating, the optimum overall pressure ratio is about 10, compared with the ratio of about 3½ for a cycle with a heat exchanger but with only one stage of heating. This larger overall pressure ratio results in a greater specific output (shaft horse-power per pound of circuit air per second), so that the plant becomes smaller for a given power output.

In Figs. 19, 20 and 21, opposite, the above cycles are shown diagrammatically. The simple open-cycle gas turbine, with an efficiency of 19·5 per cent., is shown in Fig. 19; with a heat exchanger added, as shown in Fig. 20, the efficiency is increased to 27·2 per cent.; and with the addition of a heat exchanger, intercooling and reheating, as shown in Fig. 21, the efficiency is further increased to 30·0 per cent. The thermal efficiencies are calculated on the assumption that the inlet air temperature is 60 deg. F.; gas temperature at turbine inlets, 1,200 deg. F.; compressor efficiency, 85 per cent.; turbine efficiency, 90 per cent.; heat-exchanger effectiveness, 70 per cent.; intercooler effectiveness, 70 per cent.; and turbine pressure ratio, 4 to 1. The heat-exchanger effectiveness is defined as the rise of temperature of the compressed air, expressed as a percentage of the theoretically possible rise up to the temperature of the turbine exhaust. Suitable pressure losses, and the variations in the specific heat of air with temperature, have been taken into consideration. The calculations neglect increase in weight of the gases due to fuel added, loss of heat through insulation, etc., and losses due to gland leakage and mechanical friction. In Figs. 19, 20 and 21, *a* is the compressor, *b* the combustion chamber, *c* the turbine, *d* the heat exchanger, and *e* the intercooler.

Considerable improvement in efficiency results from the incorporation of a heat exchanger in the circuit. The saving of fuel due to the preheating of the air in the heat exchanger is not obtained without certain disadvantages, the chief of which are an increased frictional pressure drop through the circuit, and, of course, the increased weight, size, and first cost of the plant. The size and weight of a heat exchanger may be reduced by designing for high air and gas velocities which would give better heat-transfer rates, but high velocities involve serious pressure drops. Again, with a given surface area of a tubular heat exchanger, the weight and size may be reduced by using a greater number of smaller diameter tubes. In the open cycle, however, the combustion gases pass through the heat-exchanger tubes, and so their diameter cannot be reduced below a size determined by considerations of fouling and cleaning. In any particular installation, a compromise must be made between these factors, depending on the relative importance of low fuel consumption, low first cost, lightness, compactness, and ease of maintenance.

The curve in Fig. 25, on this page, shows how the efficiency of a simple open-cycle plant increases with the increase in weight of the heat exchanger. The graph is based on a turbine inlet temperature of 1,200 deg. F., a compressor inlet temperature of 60 deg. F., a turbine efficiency of 90 per cent., a compressor efficiency of 85 per cent., and an expansion pressure ratio of 4 to 1. The weights given in this graph are for the tubes only, which have been taken as ¾-in. outside diameter and 18-s.w.g. thick, the weight of the shell of the heat exchanger having been omitted. It has been assumed that the arrangement of the tubes in the heat exchanger has been proportioned so that the pressure drop is the same for all sizes. In order to cover a wider range, this curve has been redrawn in Fig. 26 on a logarithmic scale, and a second curve added above to show the efficiency obtained when using smaller, tubes and high pressures on either side of the heat exchanger. The upper curve is based on ¾-in. diameter tubes and a pressure of seven atmospheres on the low-pressure side of the heat exchanger, conditions typical of a closed-cycle plant, as will be described later. This improvement in efficiency due to small tubes and high pressures is not fully obtained in the closed cycle, for there is a loss associated with the air heater of the closed cycle which partly counteracts this gain. The upper curve in Fig. 26 is intended only to emphasise the advantages of smaller tubes and higher pressures in the heat exchanger.

(To be continued.)

METROPOLITAN-LINE IMPROVEMENTS.—The reconstruction of five miles of London Transport tracks near Harrow-on-the-Hill and Preston Road stations is now being undertaken. It is intended to eliminate the bottlenecks on the Metropolitan Line in that area, in particular by doing away with the necessity for fast southbound trains to cross the local lines at Preston Road. The new fast and local lines will be independent, and the peak service on the Uxbridge (Metropolitan) line will be increased from eight to twelve trains per hour.

R.E.M.E. MEMORIAL.—A fund has been opened to enable present and former members of the Corps of Royal Electrical and Mechanical Engineers to subscribe to the Royal Military Memorial Chapel, Sandhurst. The memorial will commemorate all officers killed in the late war, and, as this will be the first occasion on which the name of the Corps will appear in the chapel, the Director of Mechanical Engineering, Major-General W. S. Tope, C.B., C.B.E., hopes that R.E.M.E. will be strongly represented among the contributors. Donations should be sent to him at the War Office, Whitehall, London, S.W.1.

LABORATORIES FOR METAL-FLOW RESEARCH, SHEFFIELD.—The British Iron and Steel Research Association, 11, Park-lane, London, W.1, have now obtained a licence for erecting limited accommodation, of temporary construction, on a site at Meadow-street, Sheffield. This temporary building will provide some further accommodation for the expanding programme of research on metal-working problems. At the present time, the Association's investigations at Sheffield are accommodated in several places, namely, in the Applied Science Department of the University, where there is an experimental rolling mill; in the works of Messrs. Arthur Lee and Sons, Limited, where there is a prototype back-pull wire-drawing machine; and elsewhere. The intention is ultimately to create a permanent building in which research on rolling, drawing, and other similar processes will be centralised. It is hoped, in time, to make these metal-flow laboratories among the best equipped for their purpose in the world. The new laboratories will constitute the sixth of the Association's out-stations, the others being the corrosion laboratory at Birmingham, the marine biological laboratory in Scotland, the experimental blast-furnace and open-hearth furnace at Stoke-on-Trent, the South Wales Laboratories at Sketty Hall, Swansea, and the physics laboratories at Battersea, London.

NOTES ON NEW BOOKS.

The Cheshire Lines Railway. By R. PRYS GRIFFITHS. The Oakwood Press, "Tanglewood," South Godstone, Surrey. [Price 6s. 6d. net (paper covers); 8s. 6d. net (cloth bound).]

RAILWAY histories are so often written by those who are not in railway service that it is worth noting that the author of this, the fifth and latest, addition to the Oakwood Library of Railway History, is a senior member of the railway staff. Having access to the official records of the Cheshire Lines Railway and an intimate knowledge of present-day working, Mr. Griffiths has been able to write a history which is authoritative, even if it is deficient in the type of quaint details which usually characterise similar books by enthusiastic laymen. The date of publication coincided with the nationalisation not only of the four main-line companies but also of the Cheshire Lines Committee—to give the railway its statutory title—which had survived the amalgamations of 1922. By an agreement of 1862, the Great Northern and Manchester, Sheffield and Lincolnshire Railways had established a joint committee to work traffic on four railways which had been authorised but had not then been built: the Stockport and Woodley Junction, the Cheshire Midland, the West Cheshire, and the Stockport, Timperley and Altrincham Junction Railways. By 1867, the new system had become an independent railway with a separate management, but controlled by the Great Northern, the Manchester, Sheffield and Lincolnshire, and the Midland Railways. It served the Liverpool-Manchester (in Lancashire) and Manchester-Chester areas; and therefore, if it had been amalgamated in 1922, logically it would have been absorbed by the new London Midland and Scottish Railway, but owing to the difficulty of assessing the loss likely to be suffered by the new London and North Eastern Railway, the Cheshire Lines Railway was not amalgamated. Locomotives were provided by the L.N.E.R., as the Committee owned none. It is interesting to note the excellent hourly service in each direction between Liverpool and Manchester which was introduced in 1877, in competition with the L.N.W.R. and the Lancashire and Yorkshire Railway. Furthermore, the Cheshire Lines reduced their fares on this route. Perhaps the title "Region," now used to denote the divisions of the national railway system, will suffer the same fate as "Committee," and the "Railways" of familiar understanding—with all their associations, happy and depressing—will persist.

Elementary Engineering Thermodynamics. By VINCENT W. YOUNG and GILBERT A. YOUNG. Third edition. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York, U.S.A. [Price 3 dols.]; and McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 18s.]

WHEN a text-book with so many competitors as confront any treatise on elementary thermodynamics attains its third edition in ten years, its substantial merits may be taken for granted. The present work provides a first course of study ranging from the elementary principles of the subject up to the theoretical treatment of the various thermodynamic cycles employed in modern methods of power production. Like most books of its kind, it covers also the theory of air compressors and refrigerating machines, while a final chapter on the properties of moist air serves as an introduction to the study of air conditioning. Numerous questions at the end of every chapter serve to test the progress of the student, though answers are not given. The book as a whole deserves its popularity, though certain criticisms may be offered. An uninformed reader, for example, would be led to believe that modern gas-turbine practice depended entirely on the simple non-regenerative open-type cycle with adiabatic compression; this whole subject might have been dealt with less sketchily in view of its current importance. Again, the theoretical treatment of air compression is by no means satisfactory. The reader is told that the work of compression can always be calculated by a well-known formula which, in fact, merely gives the area of the theoretical indicator diagram for any particular value of n in the expression PV^n. The statement is not generally true, of course, for the theoretical work must be greater than the diagram work whenever n is greater than the adiabatic exponent γ, as is necessarily the case for uncooled compression. The same mistake is to be found in many other text-books, much to the confusion of the thoughtful student. Its recurrence in the present treatise is all the more remarkable because, in an earlier chapter the authors rightly give a warning against trying to calculate the work of compression from $\int P\,dV$ under conditions where the expression is not applicable.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, etc., of the Communicators are given in italics.

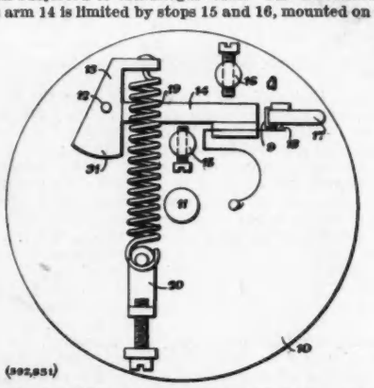
Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1s. each.

The date of the advertisement of the acceptance of a Complete Specification is given after the abstract in each case, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

AERONAUTICS.

592,851. Speed-Controlled Electric Switch. S. Smith and Sons (England), Limited, of London, and W. O. Davis, of London. (3 *Figs.*) September 19, 1944.—This invention relates to speed governor-controlled electric switches, in which a mass is moved by centrifugal force against the action of a spring to effect the operation of the switch. The objects of the invention are to overcome sluggishness in action and to reduce friction on the pivot. These results are attained by the provision of an additional mass connected to the pivot shaft and located so that the centre of gravity of the system provided by the two masses lies along, or approximate to, the line of action of the spring. A driving member 10 is mounted to rotate about an axis 11 and on the driving member there is mounted a pivot shaft 12 having two arms 13 and 14, which constitute a bell-crank lever. The arm 14 is so disposed in relation to the pivot shaft 12 and the axis of rotation 11 as to impart a turning moment to the shaft when subjected to centrifugal force. The movement of this arm 14 is limited by stops 15 and 16, mounted on the



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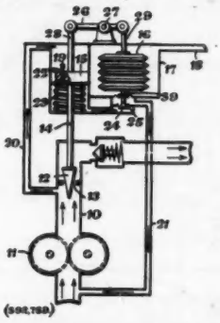
driving member. Also mounted on the driving member is a resilient switch contact 17 in the form of a U-spring which co-operates with another contact 18 carried by the arm 14. The extent of deflection of the U-spring is limited by a strap 9. Rigidly connected to the arm 13 is one end of a spring 19, the other end of which is connected by an adjustable anchorage 20 to the driving member. The tension in the spring 19 is adjusted so that when the driving member is stationary and during the first part of the range of speed, the arm 14 is held against the stop 15. In order to prevent radial thrusts being imparted to the pivot by the centrifugal force and the force of the spring, an additional mass 31 is secured to the pivot so that the centre of gravity of the system provided by the two masses lies as nearly as possible along the line of action of the spring. The invention is particularly applicable to switches for controlling the cooling systems for aero engines for different speed conditions which may prevail under conditions of cruising, climbing and fighting. It is also applicable to speed-warning devices for road vehicles. (*Accepted October* 1, 1947.)

HYDRAULIC APPARATUS.

592,769. Servo Motor for Fuel System. H. M. Hobson (Aircraft and Motor) Components, Limited, of London, and L. S. Greenland, of Weston-super-Mare, Somerset. (2 *Figs.*) May 28, 1945.—This invention relates to a hydraulic servo motor controlled by a pressure- or temperature-responsive device. It is particularly suitable for adjusting the rate of flow of fuel to an aircraft engine as a function of atmospheric or boost pressure, or as a function of induction temperature, or both. Fuel is pumped to the combustion chamber of the engine along a pipe 10 by a fuel pump 11. The rate of flow of fuel is controlled by a needle valve 12, axial movement of which varies the effective area of a metering orifice 13. The valve 12 is coupled by a rod 14 to a servo piston 15, the position of which is controlled by a stack of pressure-responsive capsules 16 situated in a chamber 17 exposed to air-intake pressure, admitted to the chamber through the pipe 18. The upper end of the servo cylinder 19 communicates, through an inlet conduit 20, with the fuel-delivery pipe 10, on the upstream side of the metering orifice 13. To the lower and low-pressure end of the servo cylinder is connected an outlet conduit 21 through which fuel can return from the servo cylinder 19 to the suction side of the pump. A calibrated orifice 22 in the servo piston 15 permits a restricted flow of fuel from top to bottom of the cylinder, and a compression spring 23 at the low-pressure side of the servo piston 15 holds the latter balanced against the hydraulic pressure difference acting on it. A rod 39 fixed to the lower end of the capsule stack carries a valve 24 controlling the area of an orifice 25 in the outlet conduit 21, and a



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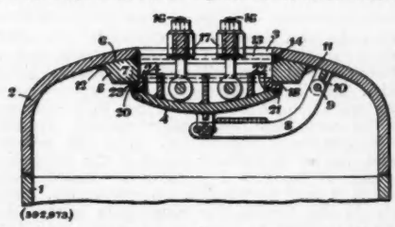
follow-up lever 26, pivoting on an intermediate fulcrum 27 is pivoted at its opposite ends to rods 28, 29 connected, respectively, to the upper end of the servo piston 15 and the capsule stack 16. On expansion of the capsule stack 16, due to reduction in air-intake pressure, the associated valve 24 will move down to increase the area of the orifice 25. This increases the pressure difference across the servo piston 15, which moves down against the spring 23 causing the needle valve 12 to reduce the area of the fuel-metering orifice 13. The follow-up lever 26 raises the capsule stack 16 and the movement of the servo piston 15 ceases when the valve 24 has been restored to its initial position. On increase of the intake pressure, the reverse action takes place, the servo piston 15 being moved up by its spring 23 to increase the area of the fuel-metering orifice 13. (*Sealed.*)

STEAM ENGINES, BOILERS, ETC.

592,973. Inspection Cover for Steam or Water Drums. G. S. Pounder, of Blackheath, London. (4 *Figs.*) January 24, 1944.—The invention relates to an inspection cover for the steam or water drum of a boiler. Its object is to avoid weakening and distortion of the metal around the hole in the drum and thus enable it to withstand high pressures. The construction is shown applied to a drum 1 having an outwardly-dished end 2. The inspection hole 3 has a ring 5 welded to the inner surface of the drum end 2, its outer surface 6 conforming with the concave inner surface of the drum end so that it fits snugly on that surface around the inspection hole 3 without bending the metal of the drum end inwards around the hole. The inner surface 7 of the ring 5 is machined to provide a seating for the cover 4 which is mounted by an arm 8 to hinge at 9 on a lug 10 which projects inwards from the drum end 2 at one side of the ring 5. The outer periphery 11 of the ring is flared so as to provide, between it and the



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inner surface of the drum end, a recess to receive welding metal at 12 for mounting the ring in position. The welding is supplemented by another weld 13 at the internal periphery of the ring, the latter and the drum end 2 being machined to form an annular recess 14 of taper section to receive the welding metal. The usual type of bolts 16 and bridge-pieces 17 are used for clamping the cover 4 to the seating on 7 with the interposition of a packing washer 18. The cover 4 is constructed of a concave dished member to which a ring 20 is welded externally at 21 and internally at 22. The ring is machined to form a companion seating 23 to the seating at 7 on the ring 5, and to provide the door with a spigot 24 to fit inside the ring 5. This design of internal seating is very efficient and will withstand very high pressures, while the stresses at the welds 12, 13, 21 and 22 are very low and the welds are not in shear. (*Sealed.*)